Incompressible Encryption

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(This is joint work with Rishab Goyal, Venkata Koppula and Aman Verma)

Contents

Contents

- Introduction

Contents

Contents

- Introduction
- Security Definitions
- Incompressible SKE & PKE

Contents

Contents

Introduction

Encryption Scheme

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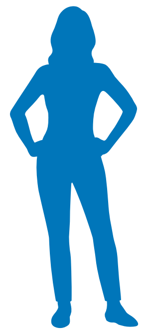

ALICE

Encryption Scheme

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BOB

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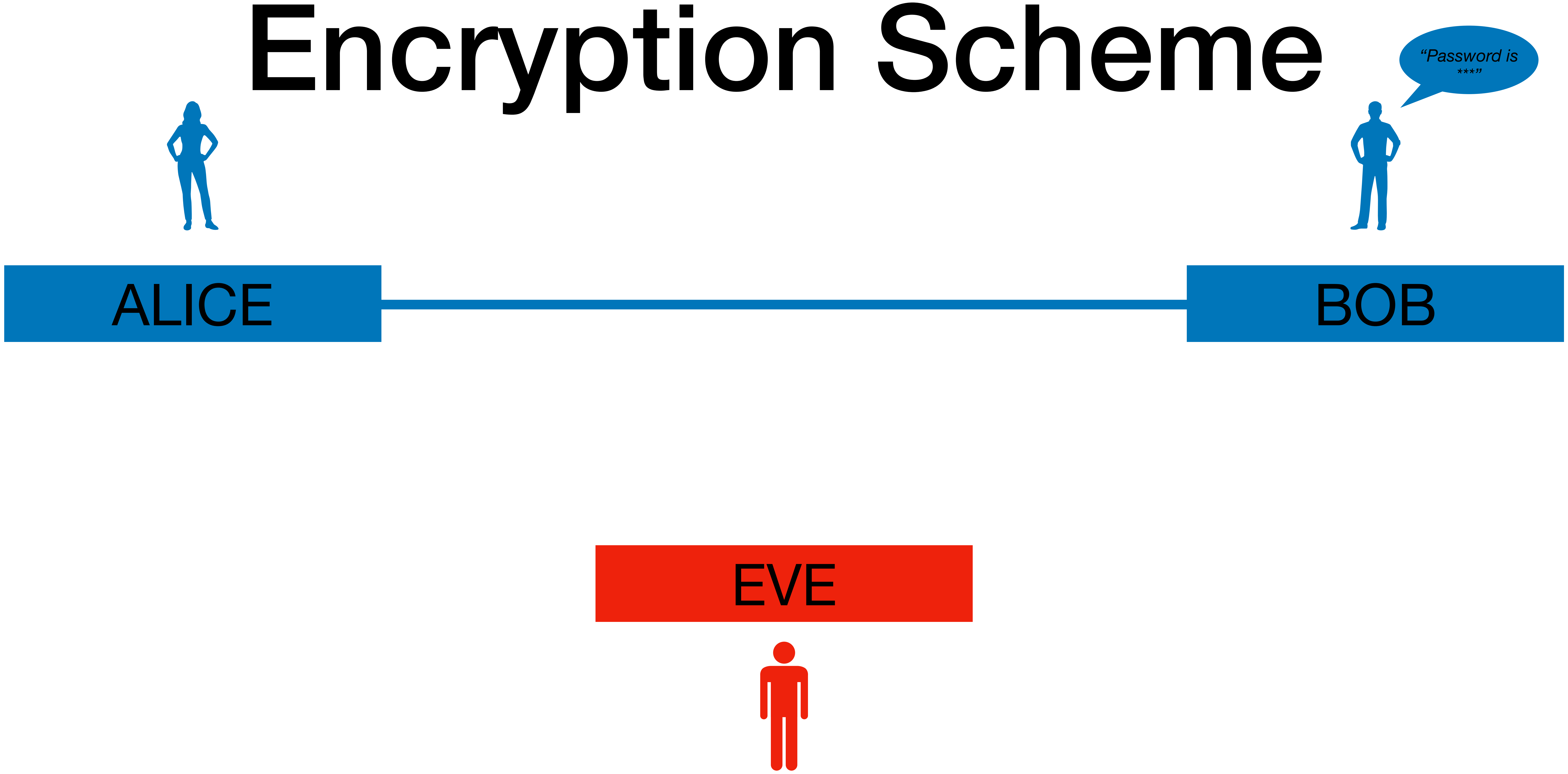

ALICE

BOB

EVE

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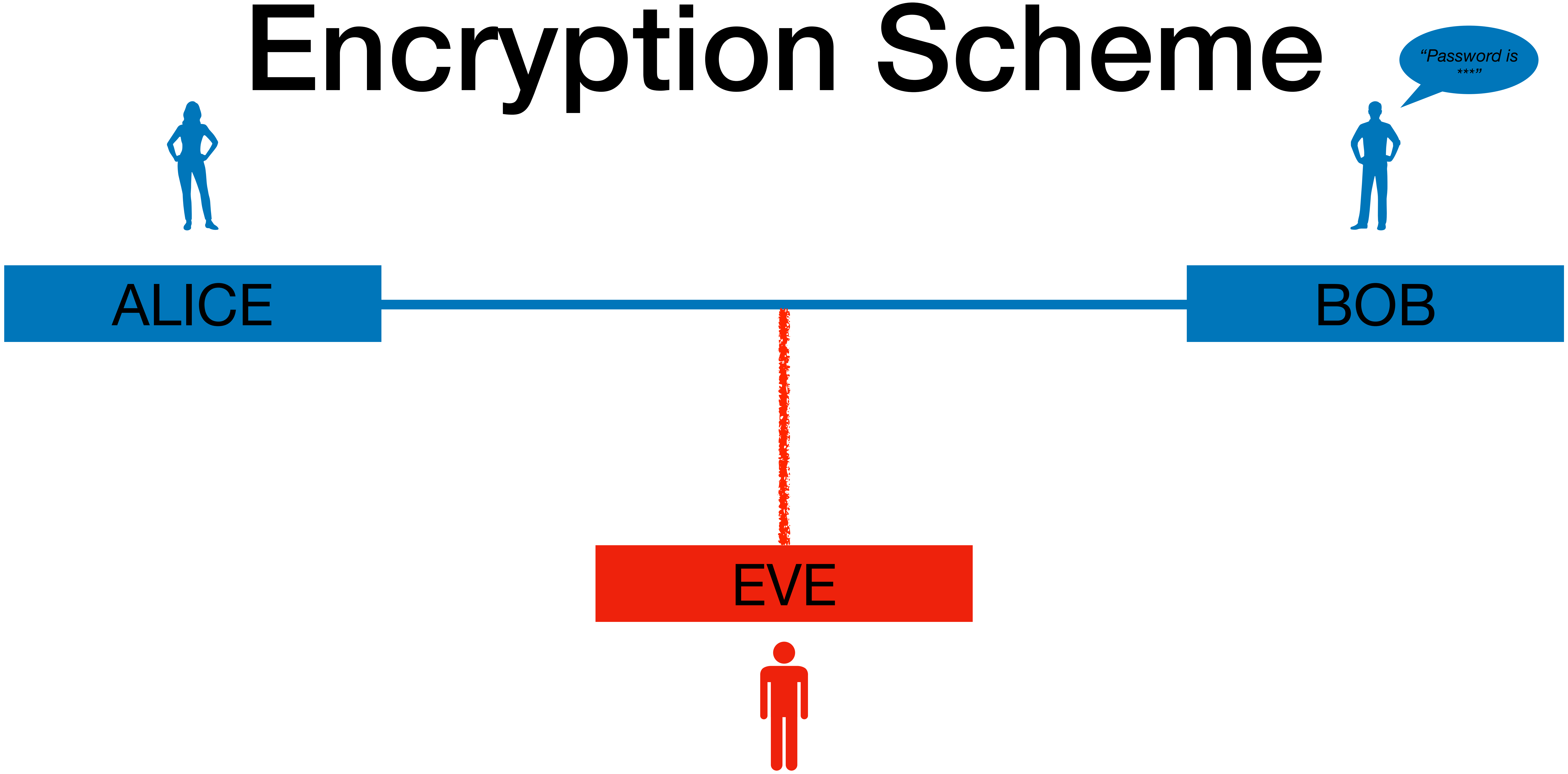

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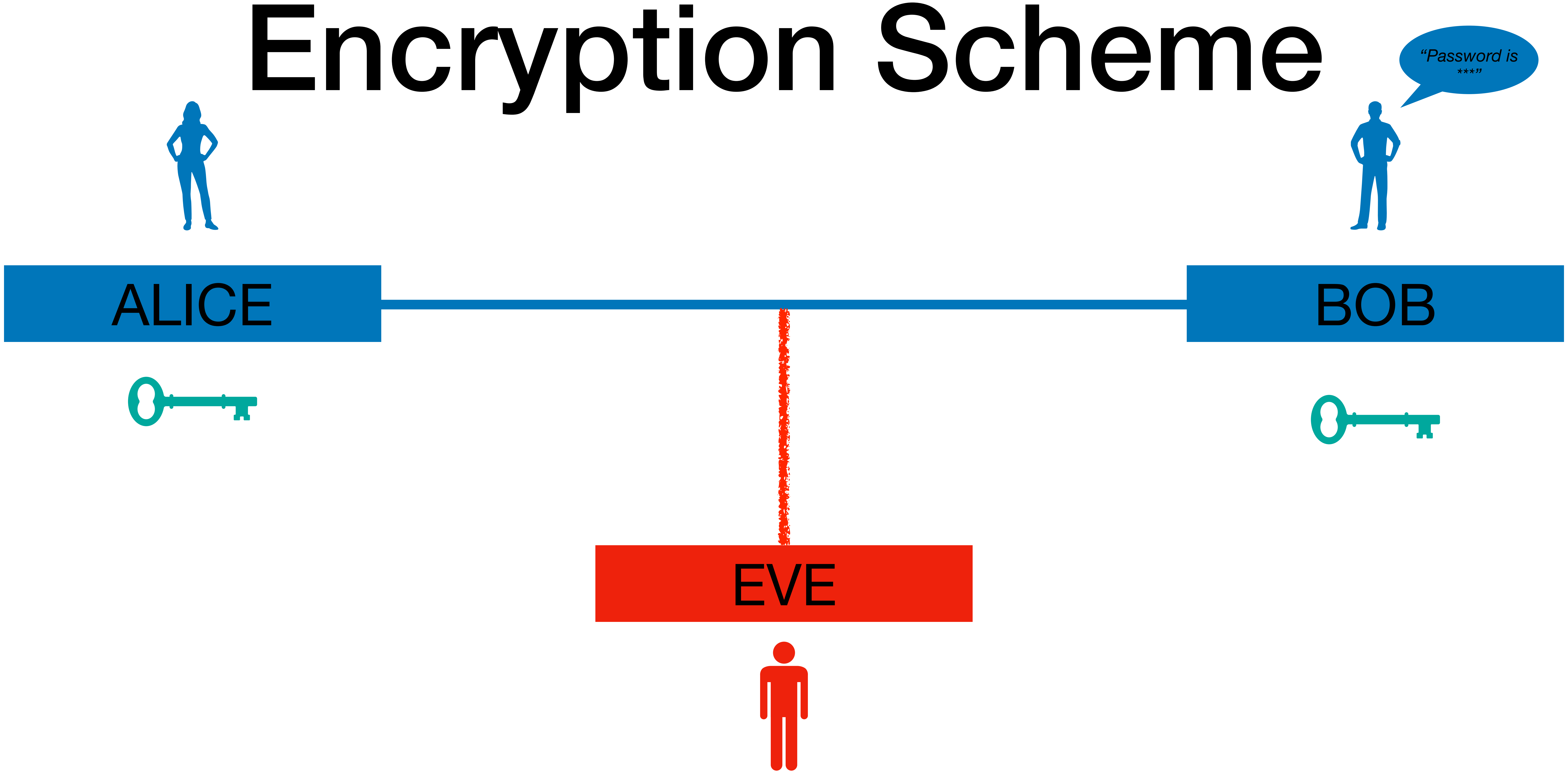

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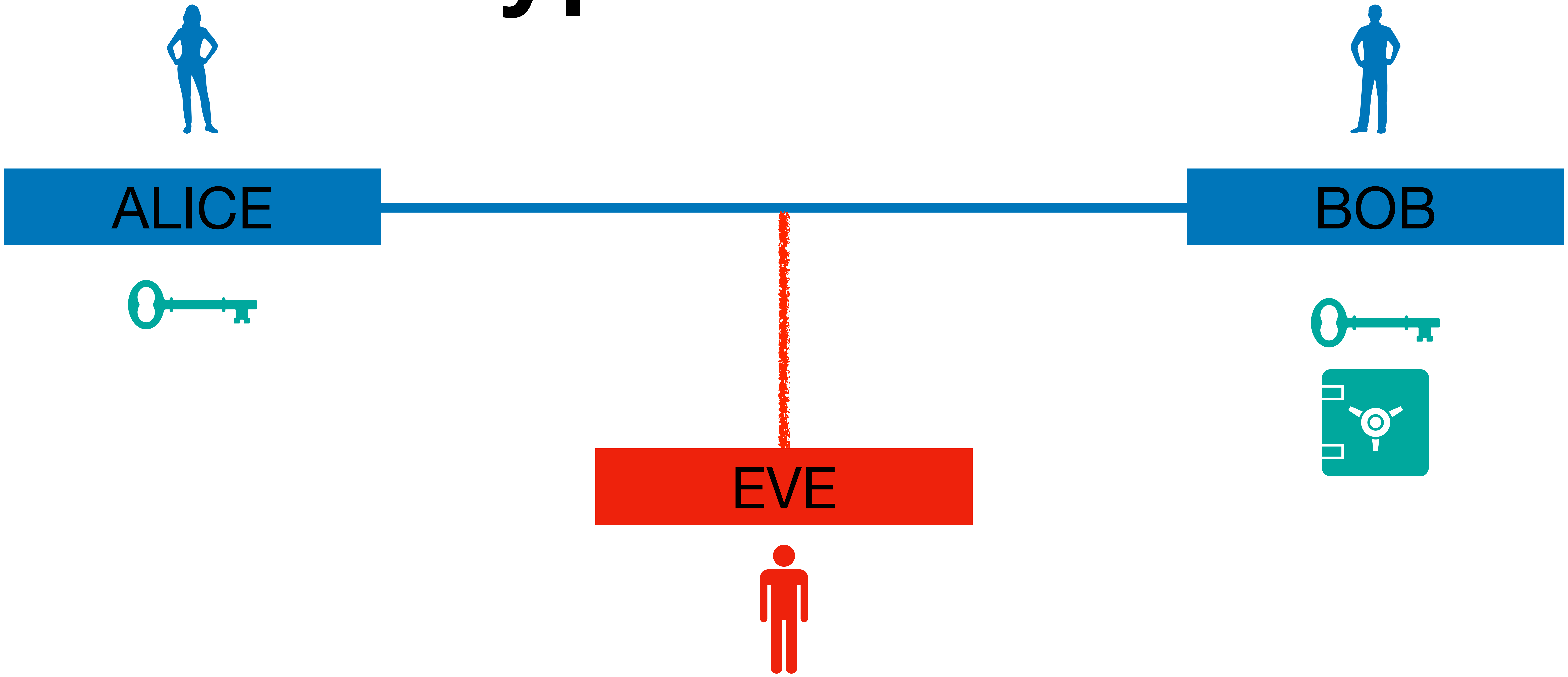

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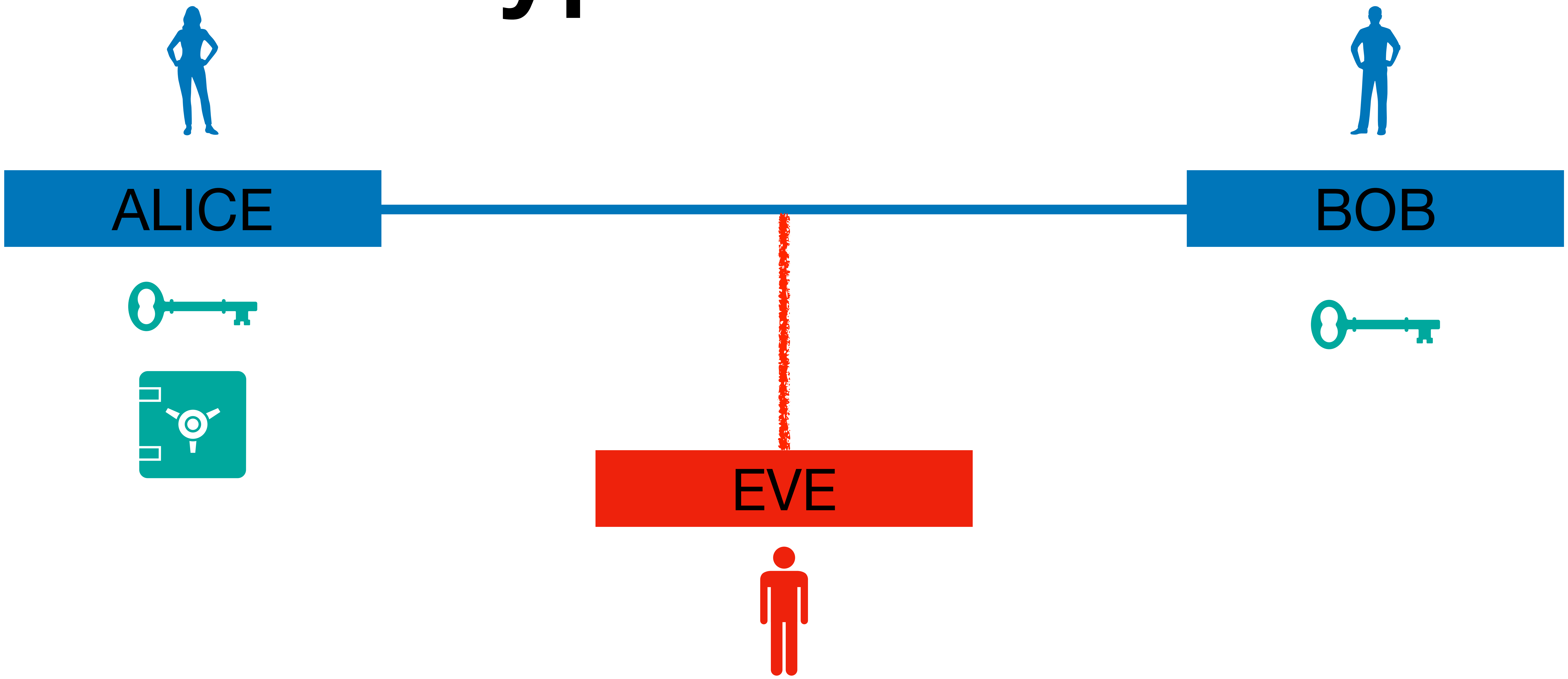

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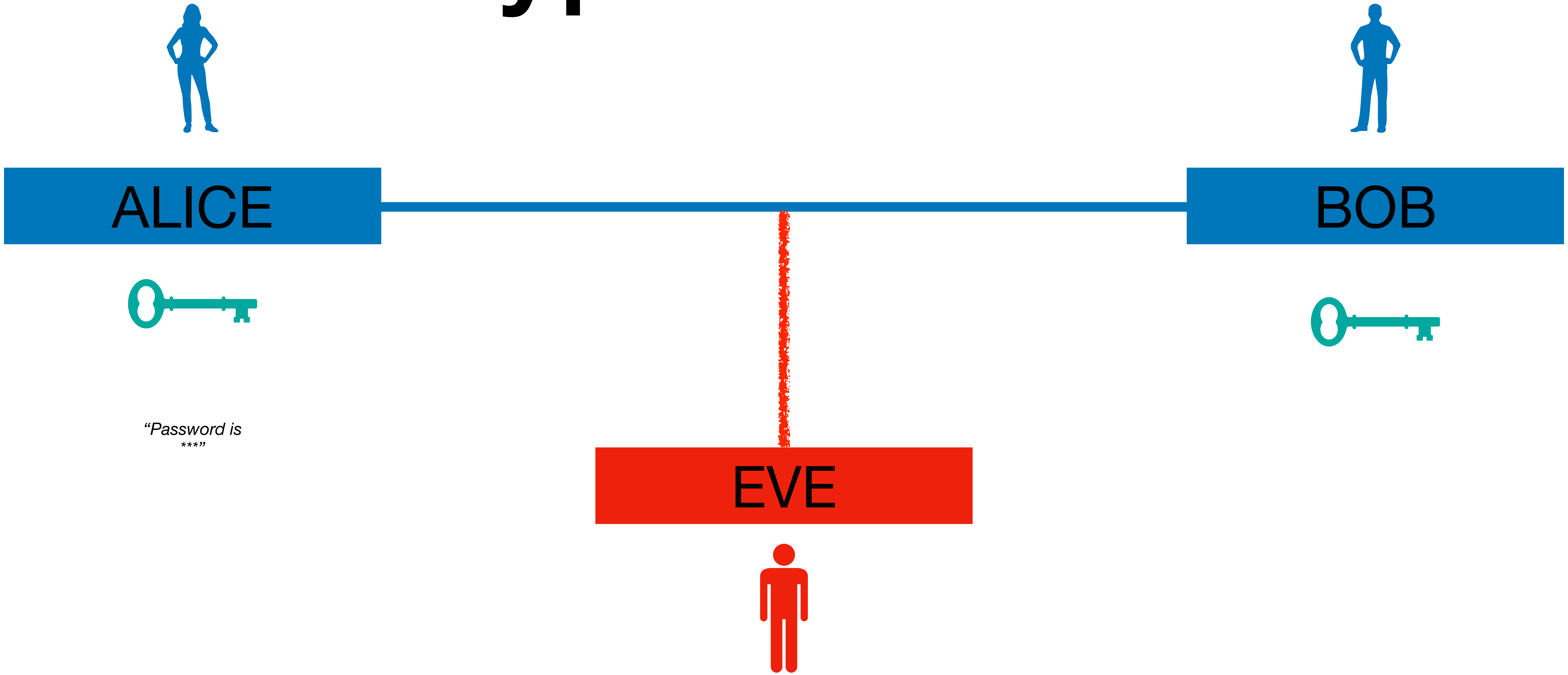

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*“Password is ***”*

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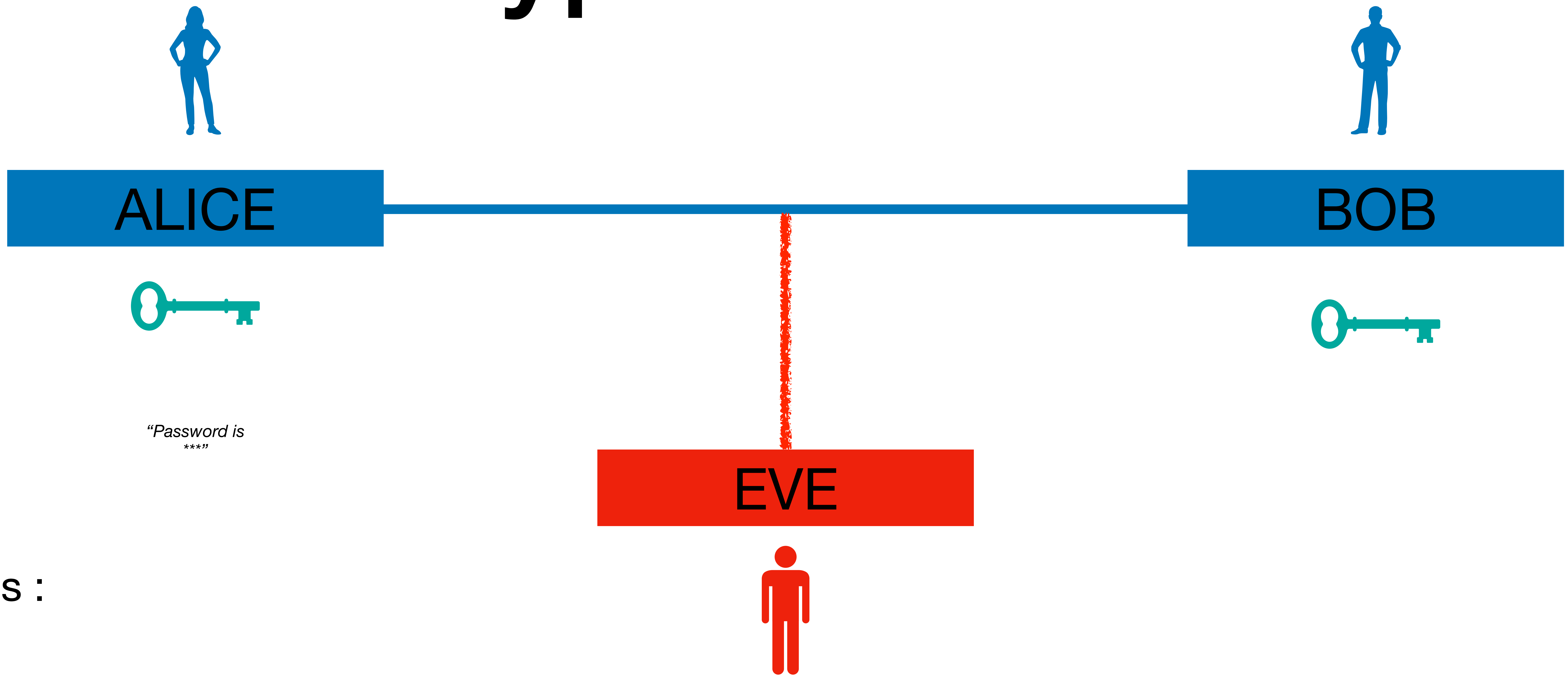

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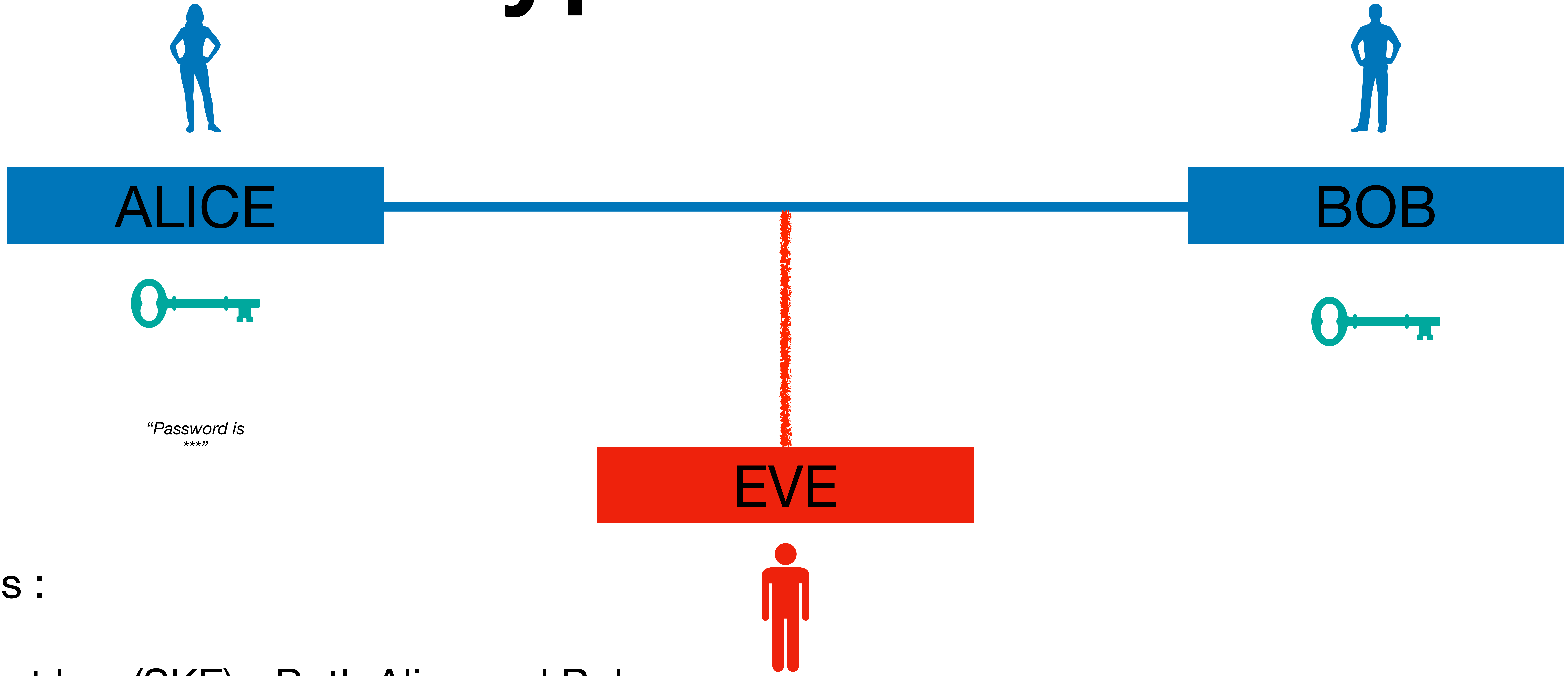

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2 types :

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

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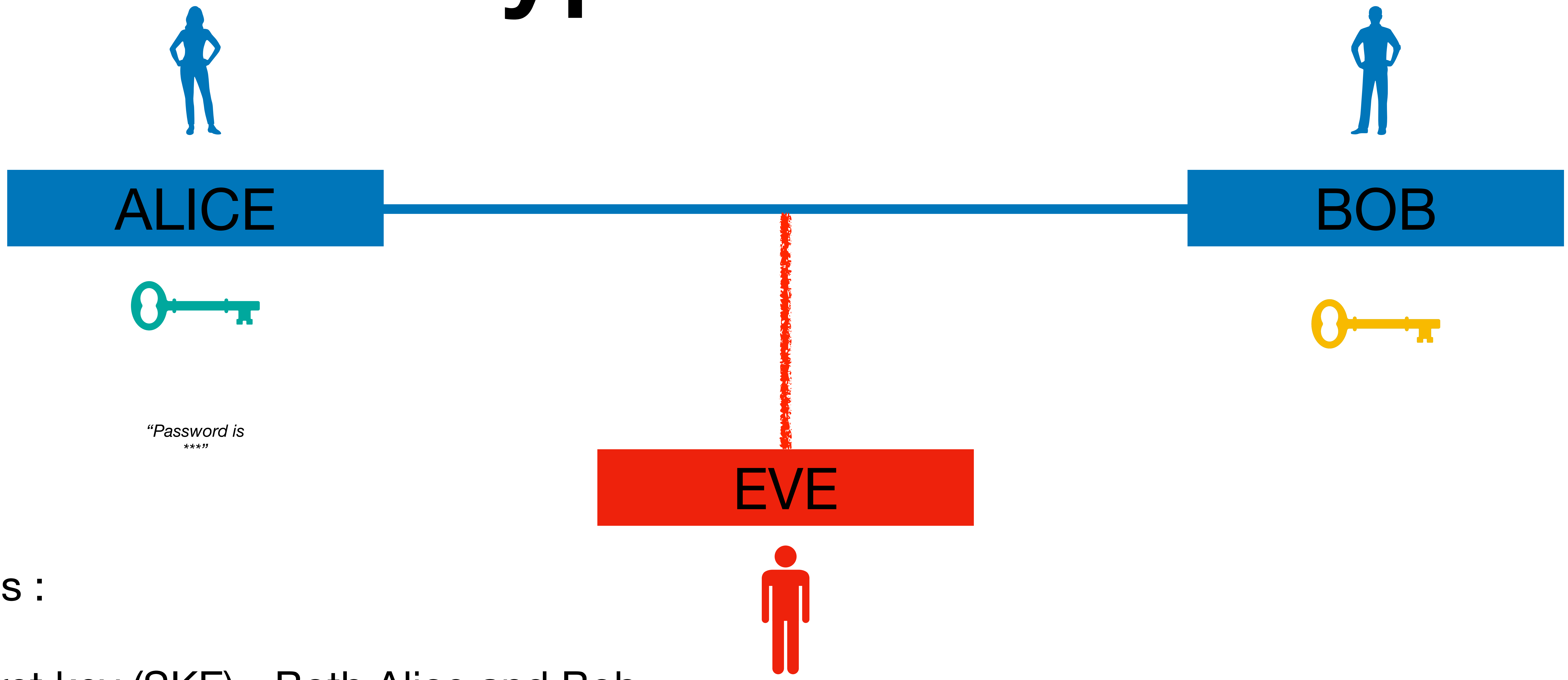

2 types :

- secret key (SKE) - Both Alice and Bob have the same key.
- public key (PKE) - Encryptor has public key and decrypt has secret key.

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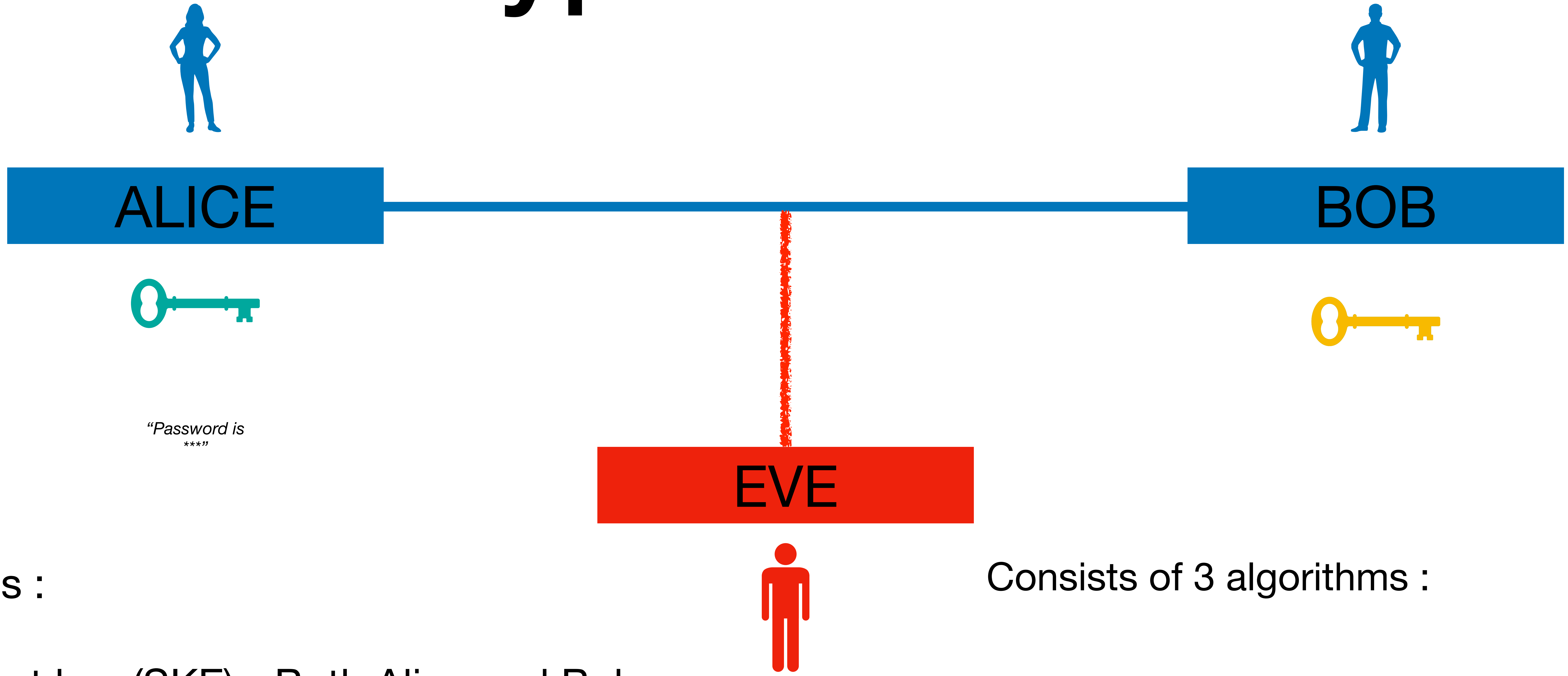

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Consists of 3 algorithms :

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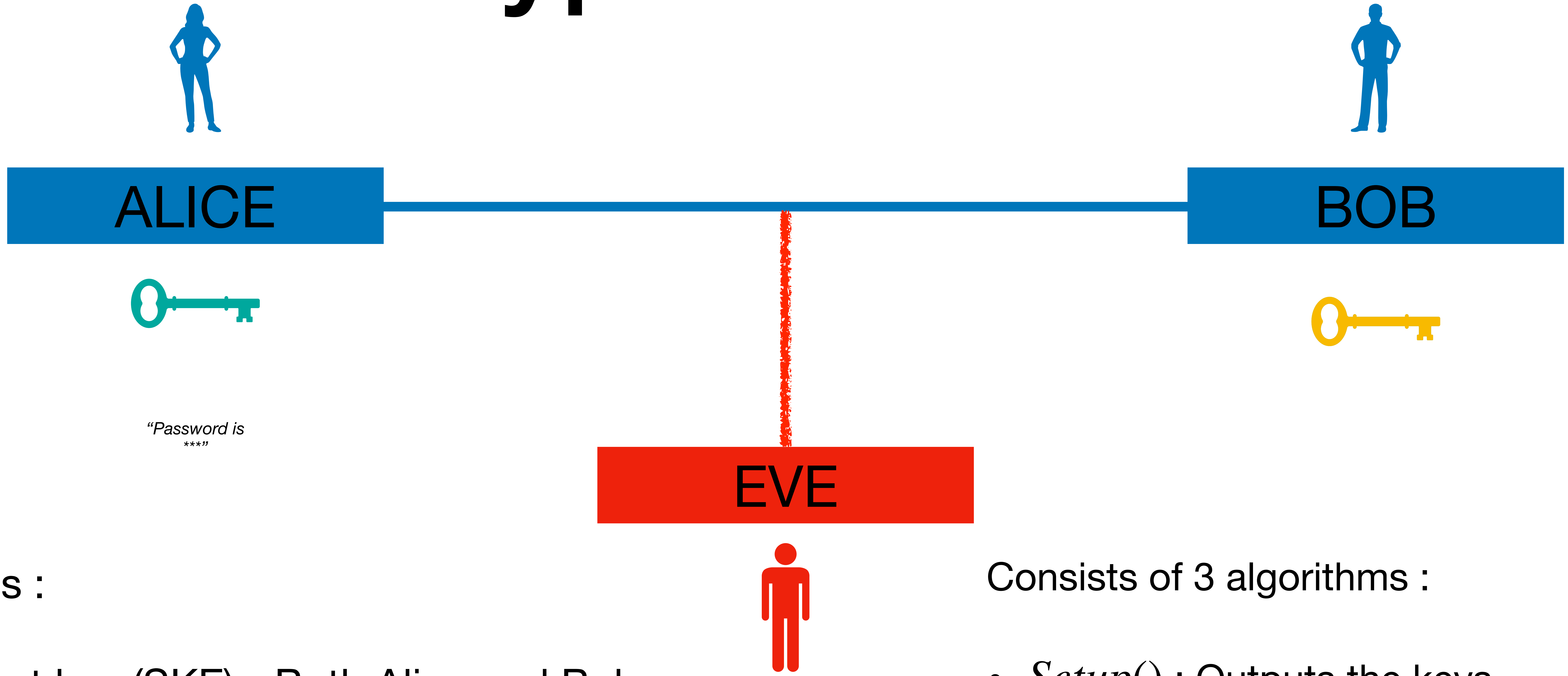

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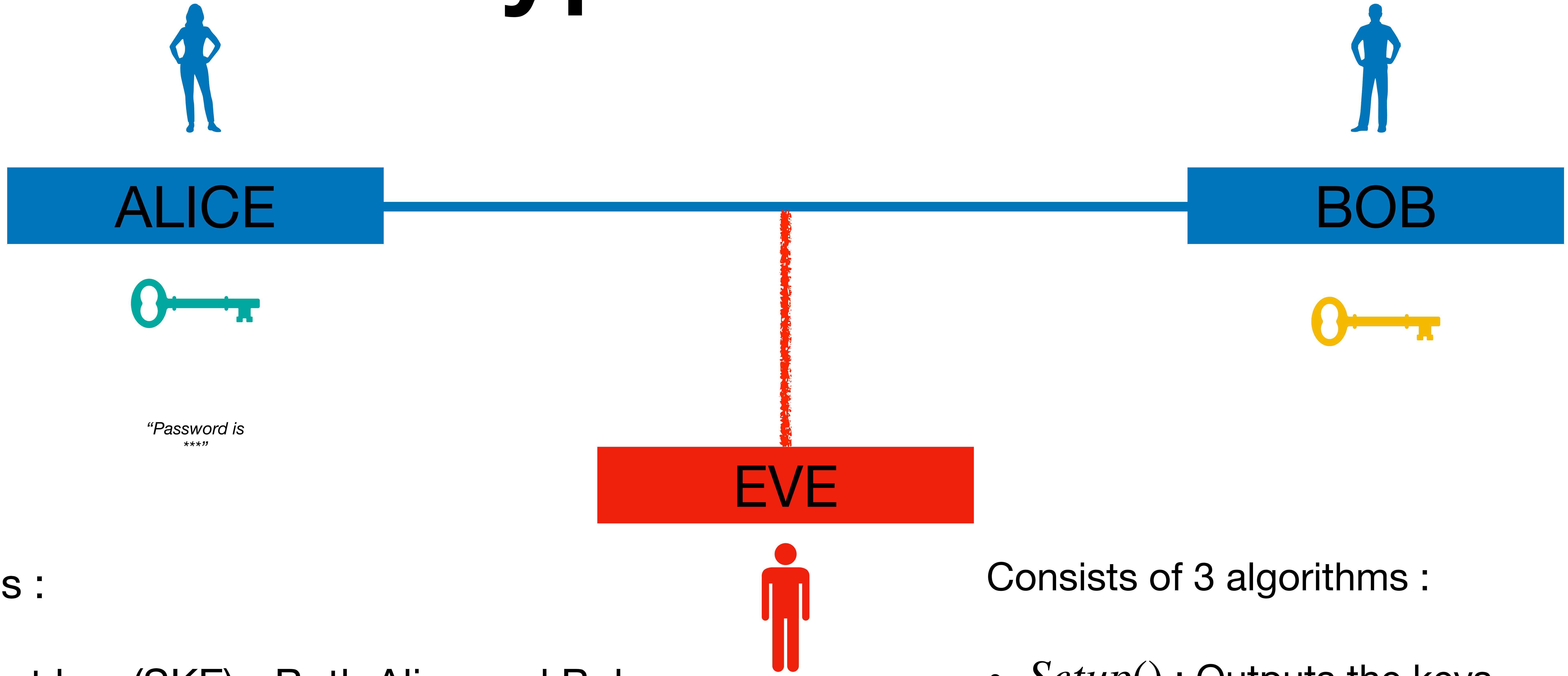

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Consists of 3 algorithms :

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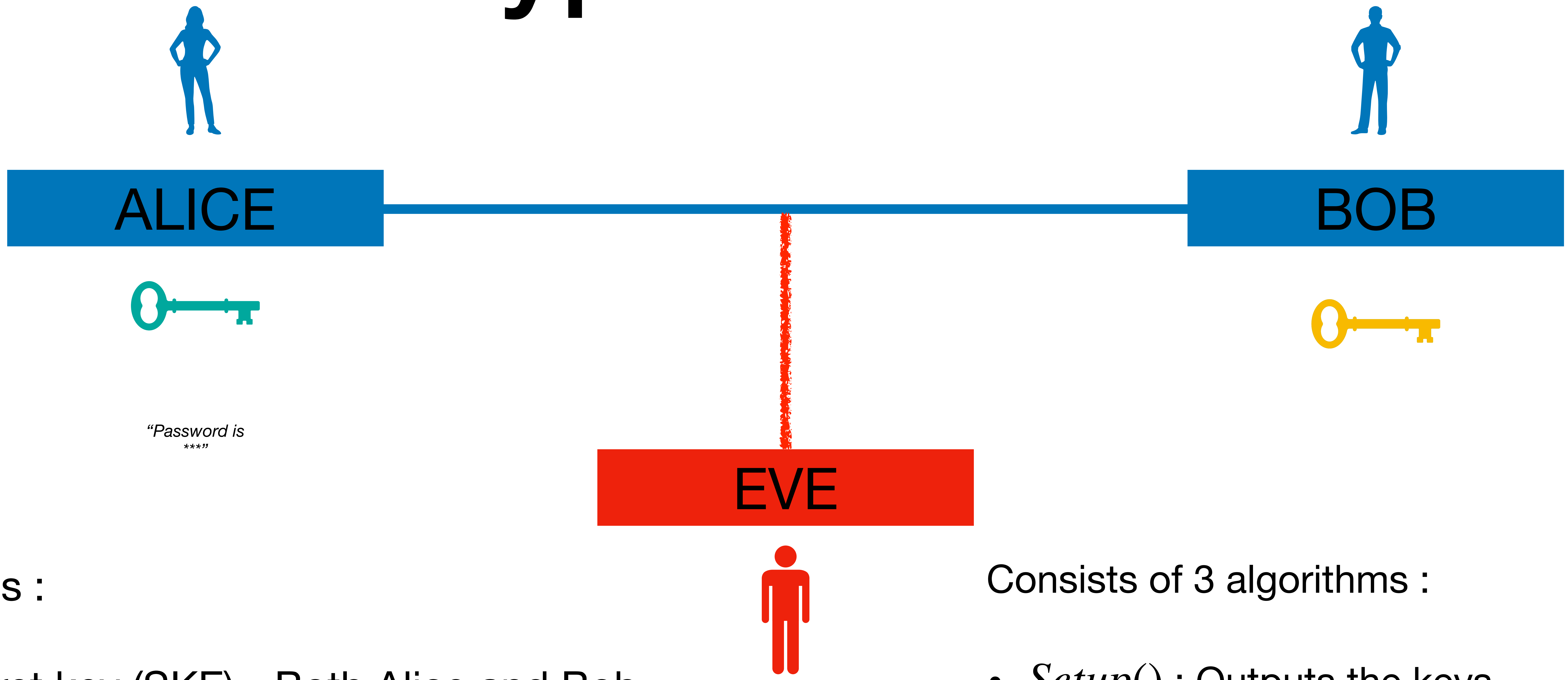
- $Enc(pk/sk, m)$: Outputs ciphertext

Encryption Scheme



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- secret key (SKE) - Both Alice and Bob have the same key.
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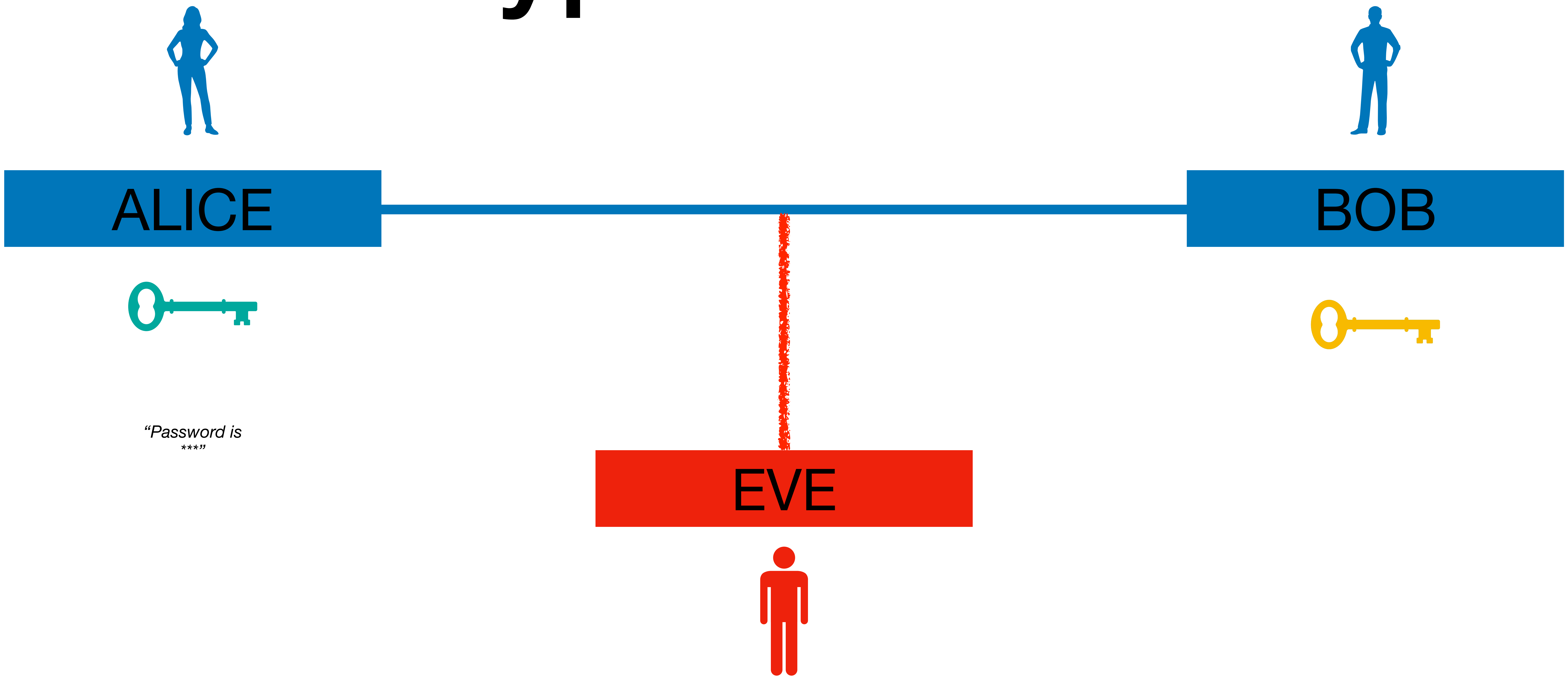
Consists of 3 algorithms :

- $Setup()$: Outputs the keys
- $Enc(pk/sk, m)$: Outputs ciphertext
- $Dec(sk, c)$: Outputs message or error

Encryption Scheme



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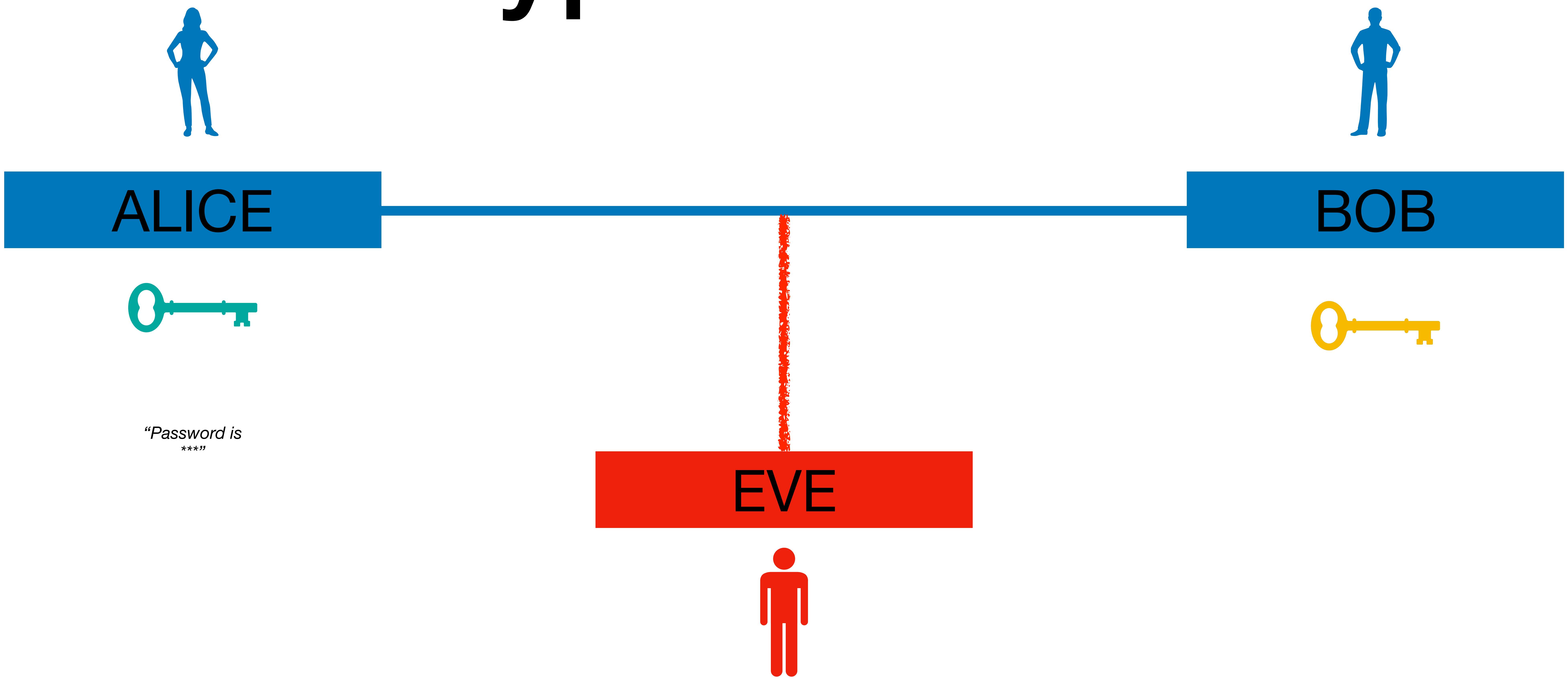

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- Correctness - $Dec(sk, Enc(pk, m)) = m$

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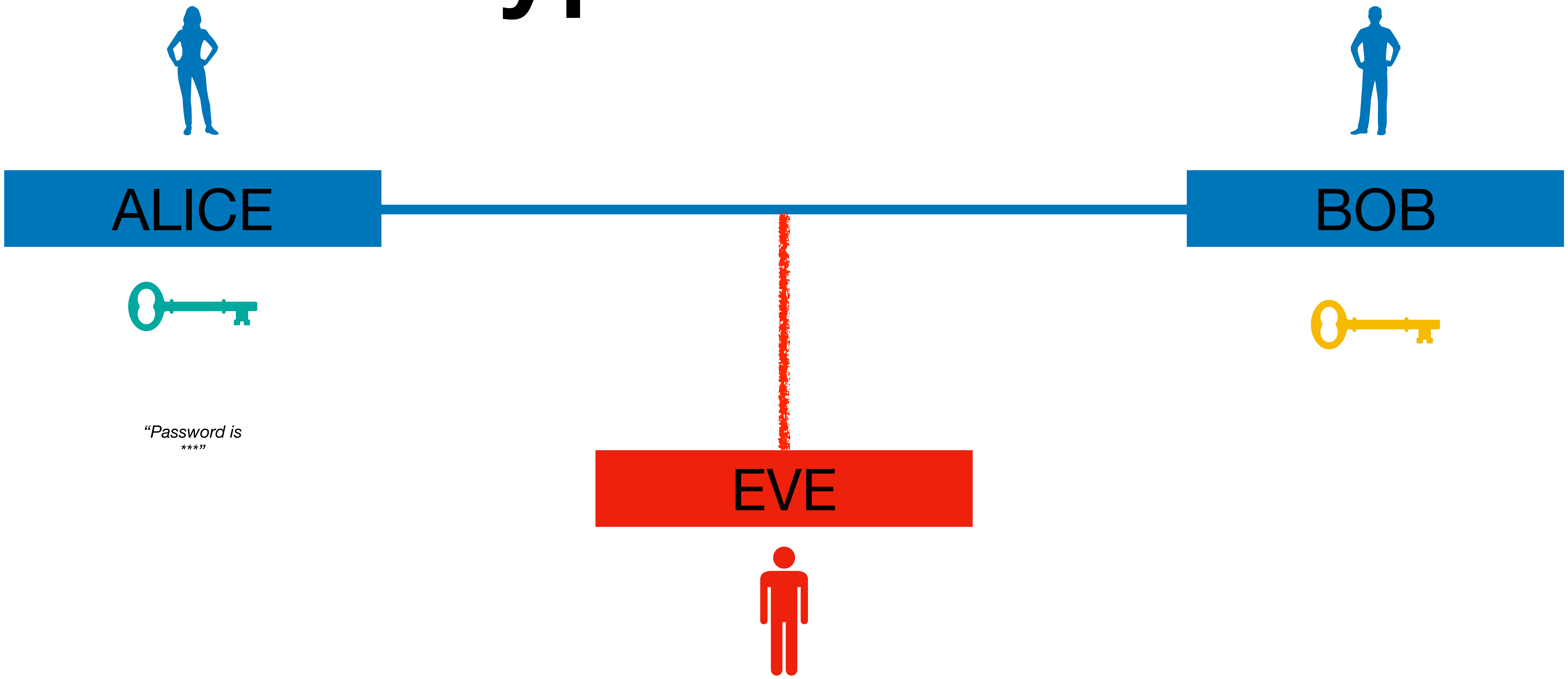

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- Security - …….

Security Definitions

Standard Security [Goldwaser,Micali84]

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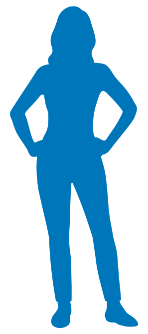
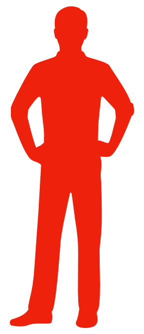
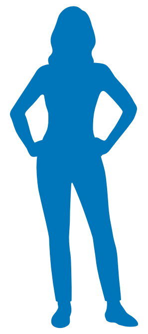


Challenger



Adversary

Standard Security [Goldwaser,Micali84]



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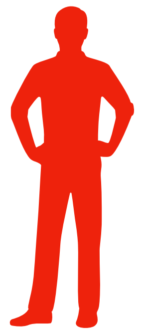

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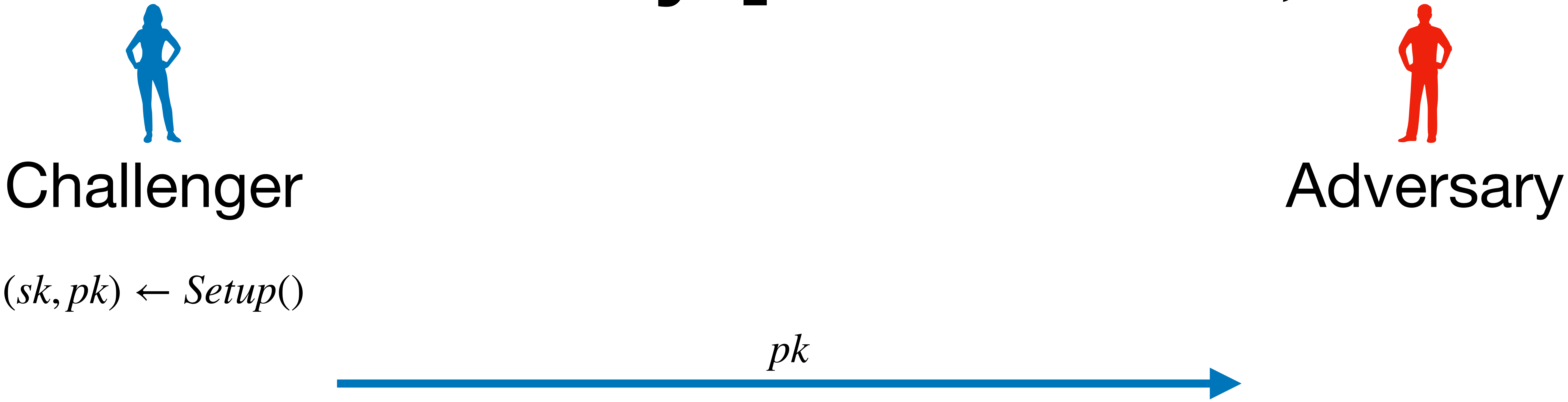

Challenger

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$$\xrightarrow{pk}$$

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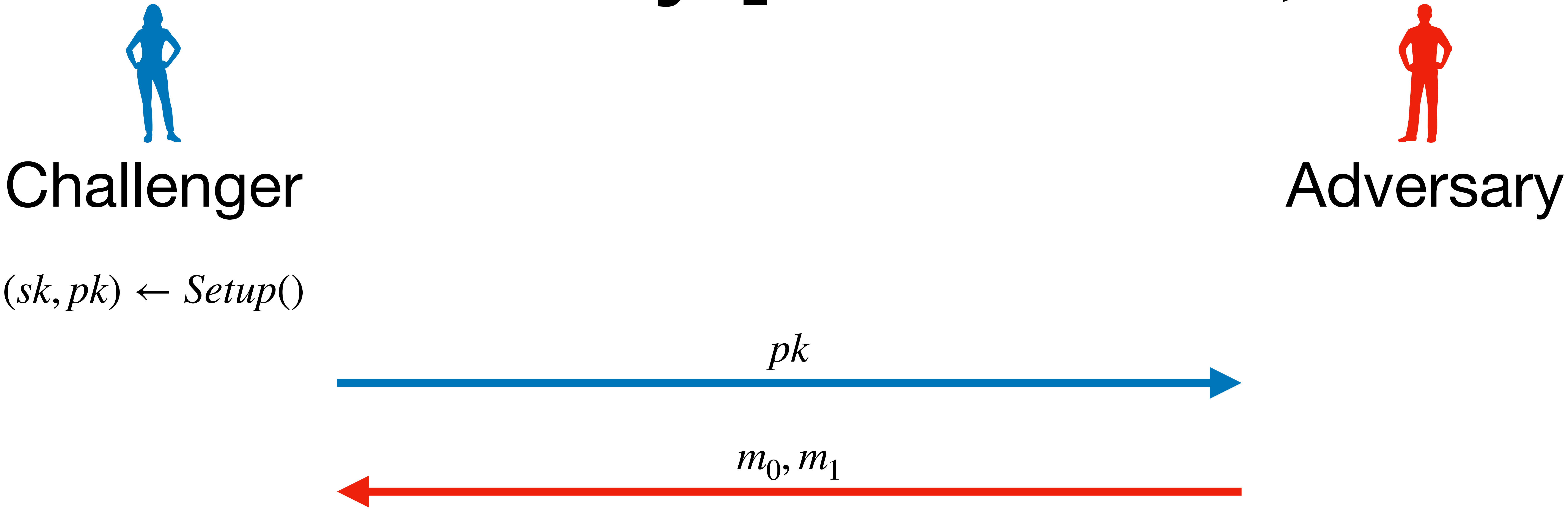

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m_0, m_1

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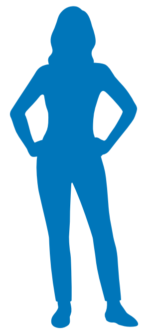

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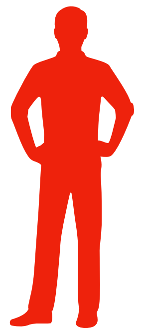

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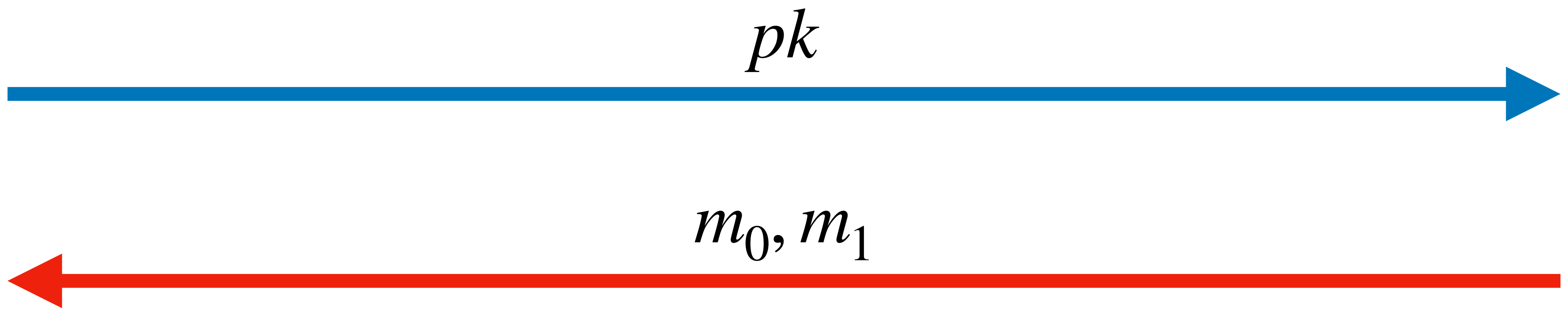

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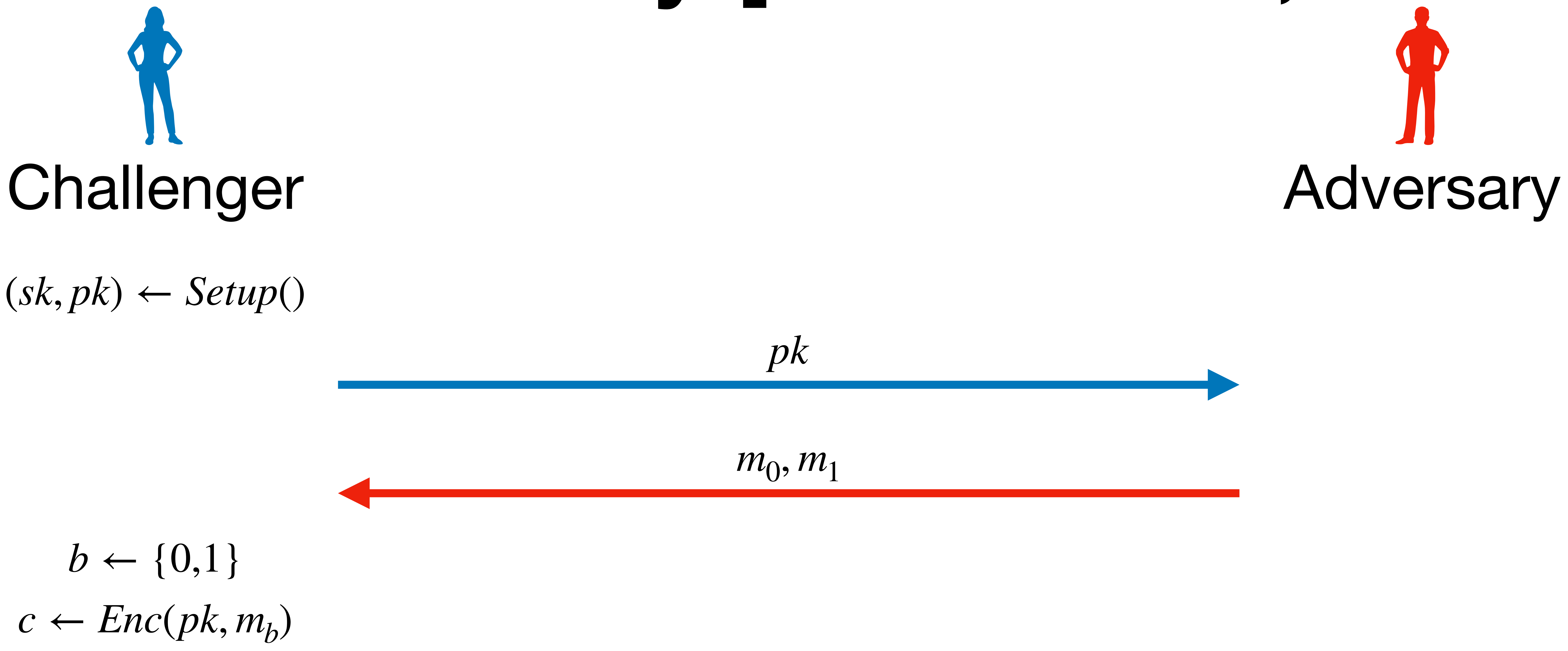

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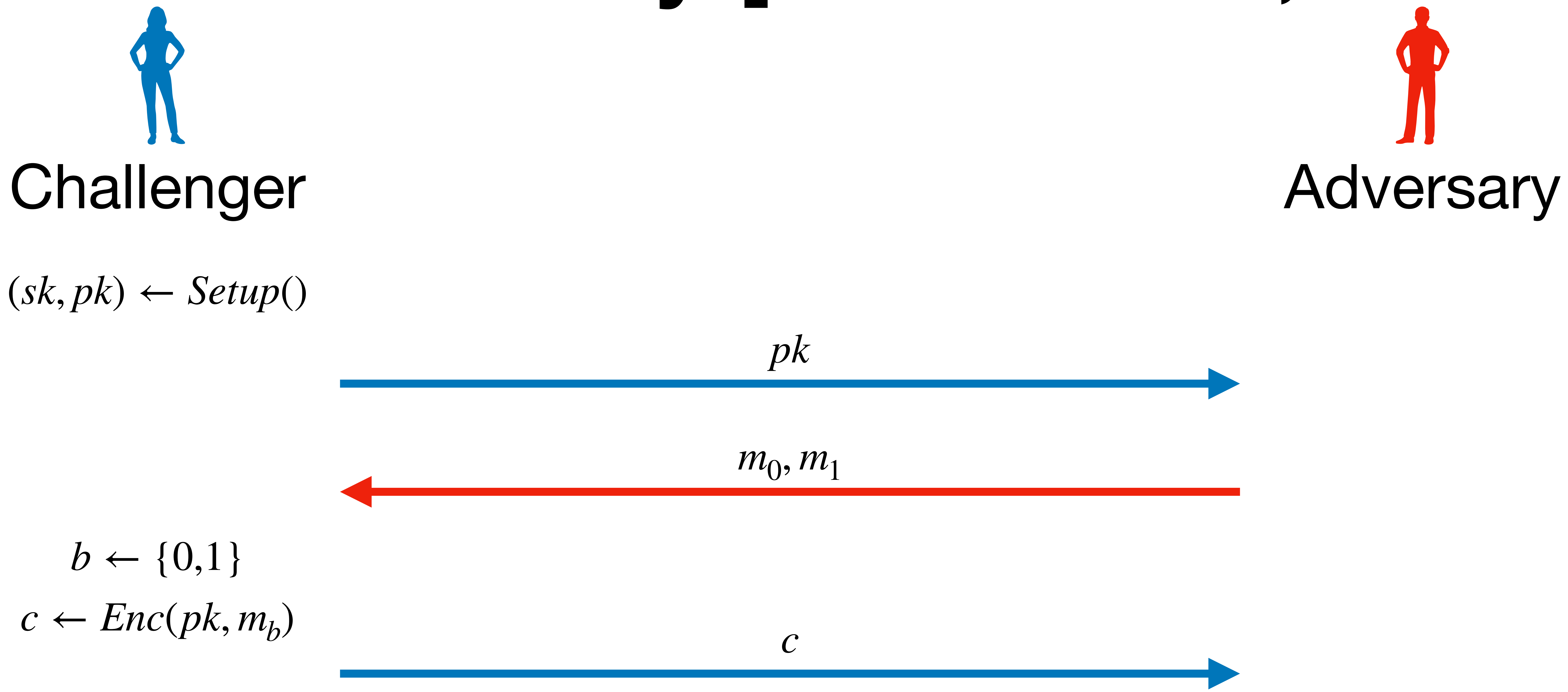

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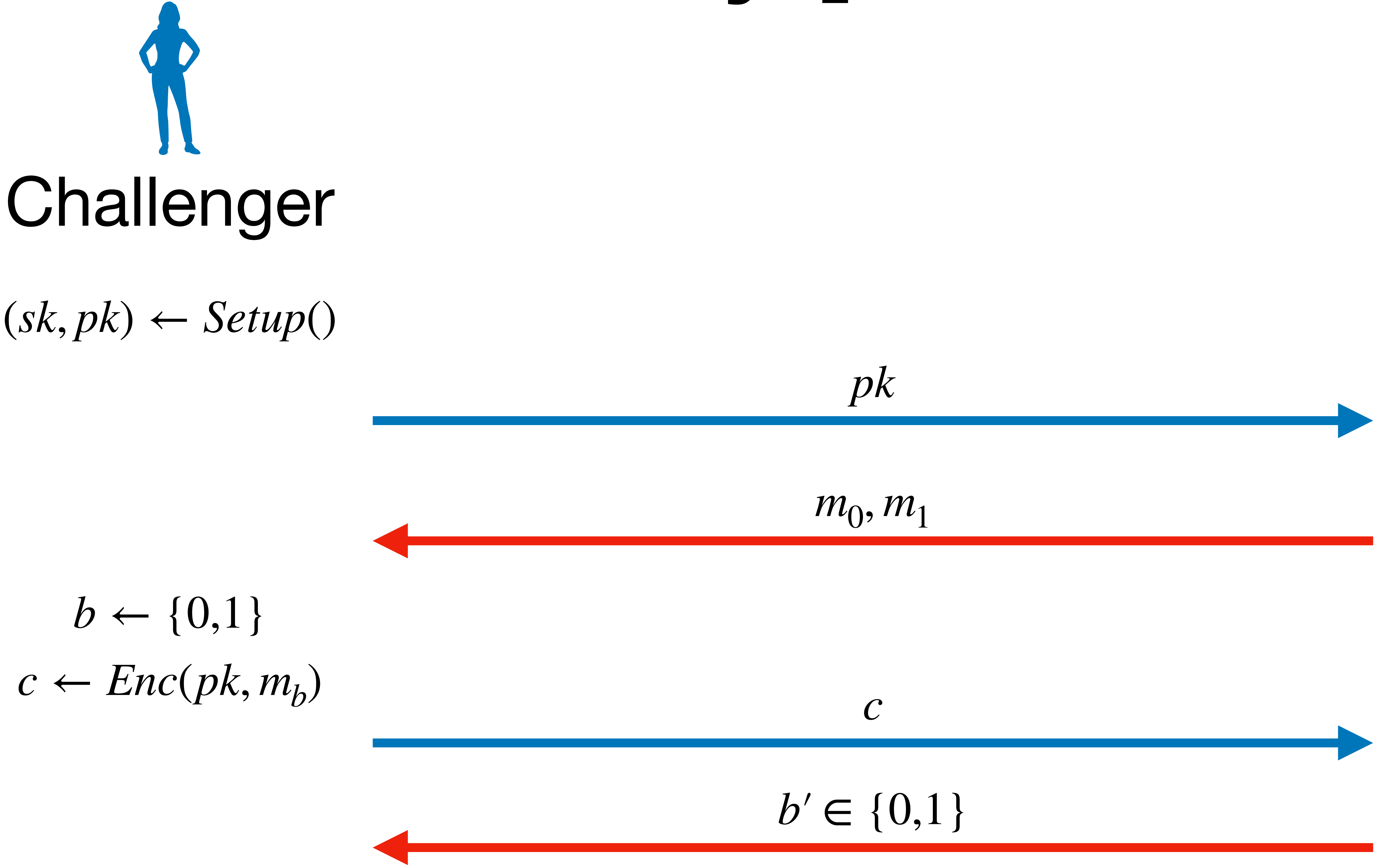

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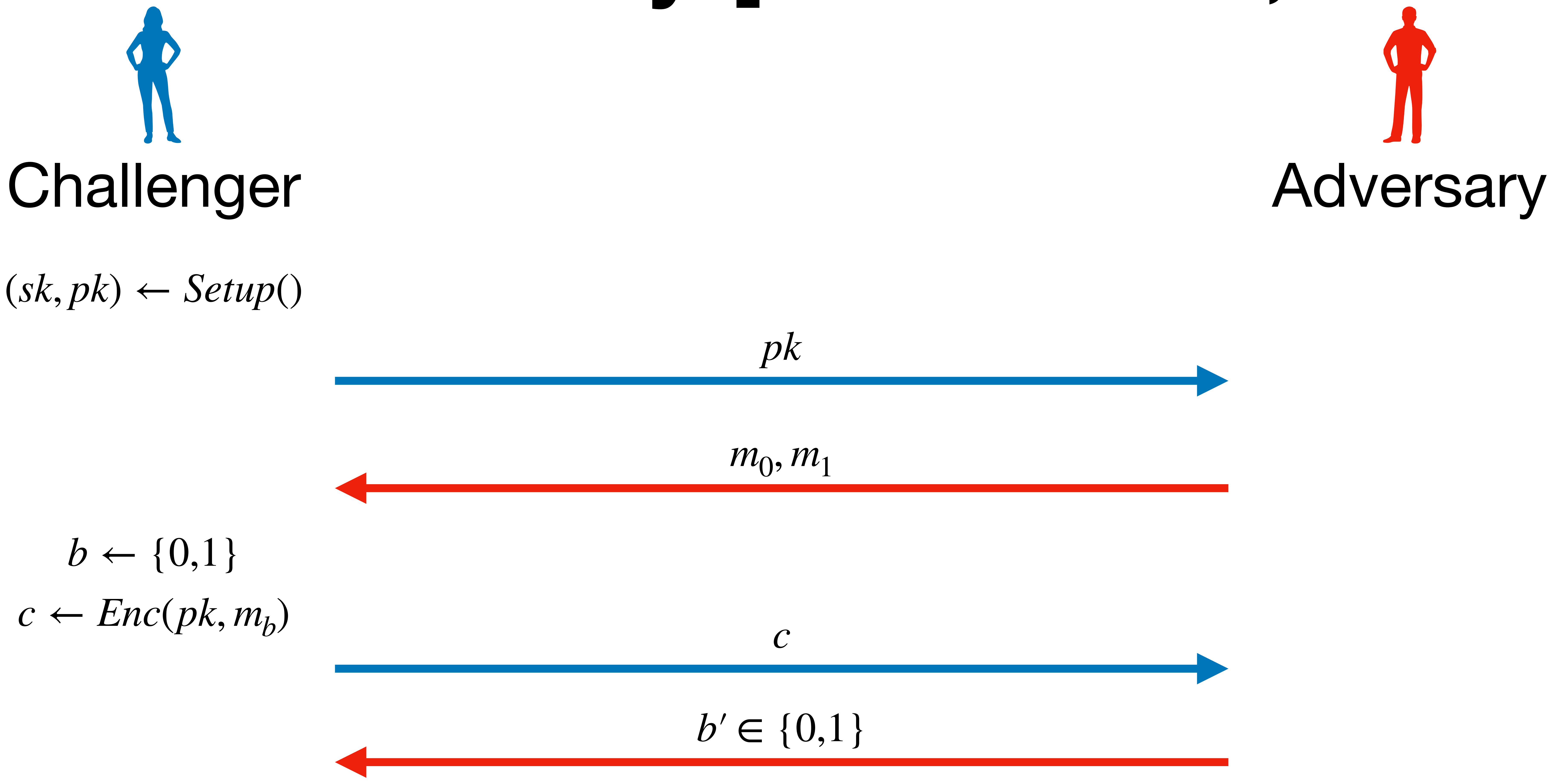

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Adversary wins if $b = b'$

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

Security against Leakage

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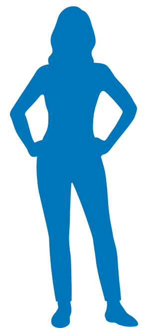

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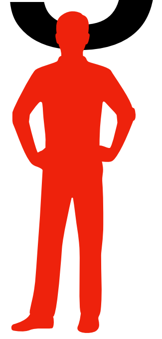

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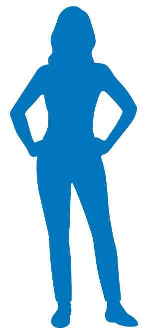

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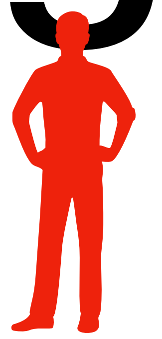

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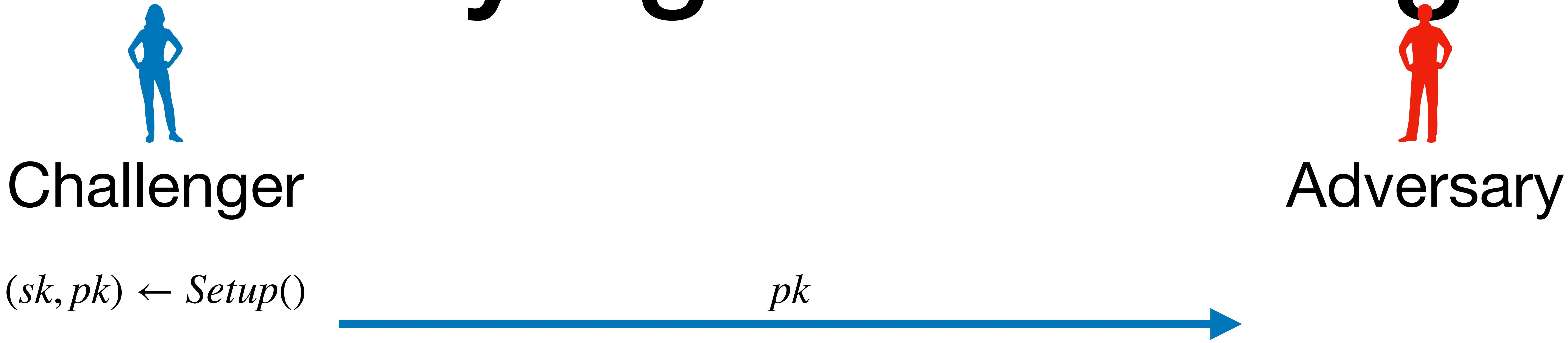

Challenger

Adversary

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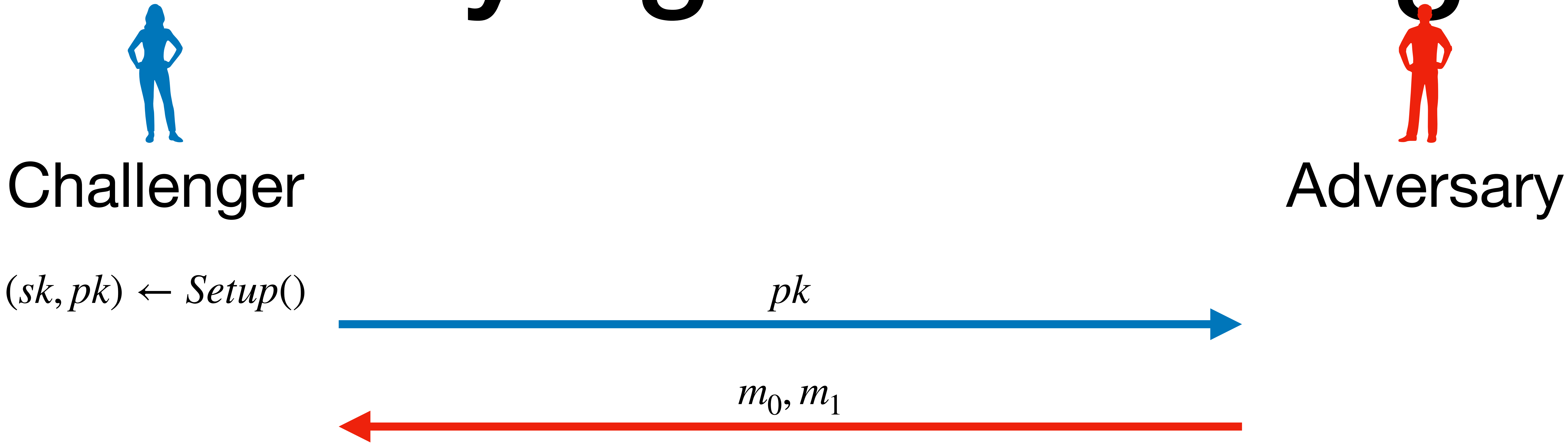
$\xrightarrow{pk}$

Security against Leakage



Challenger

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m_0, m_1

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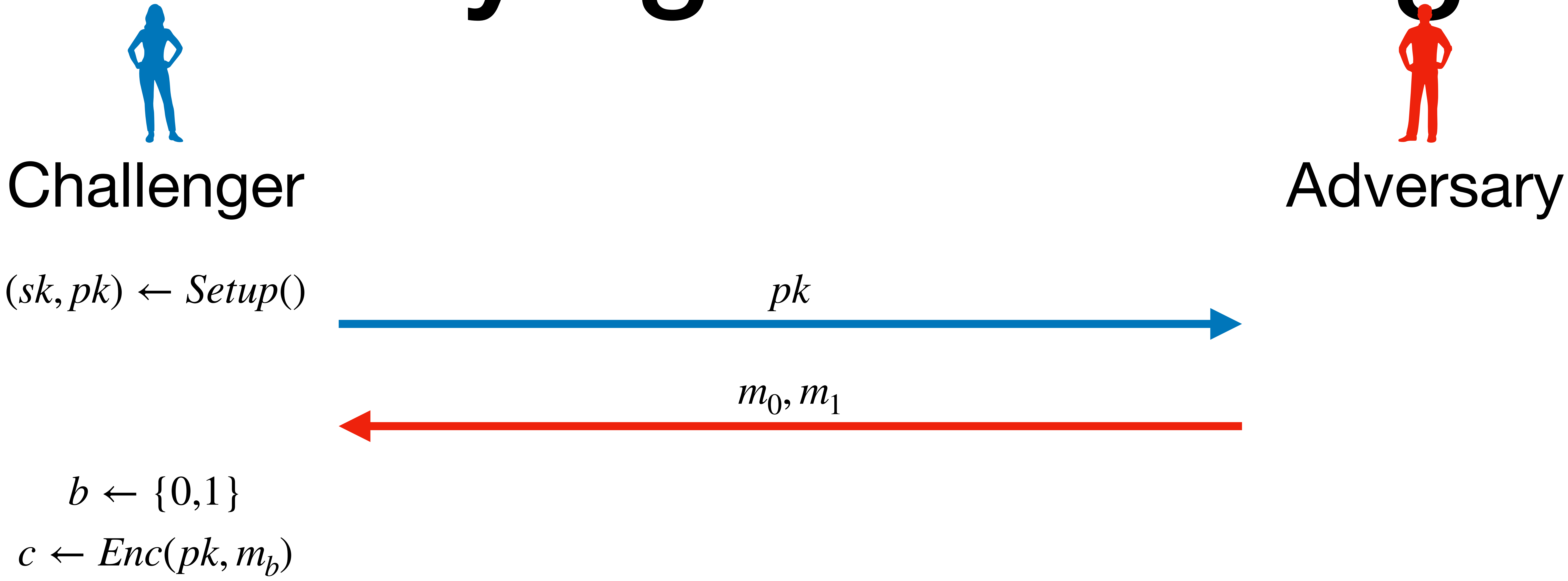

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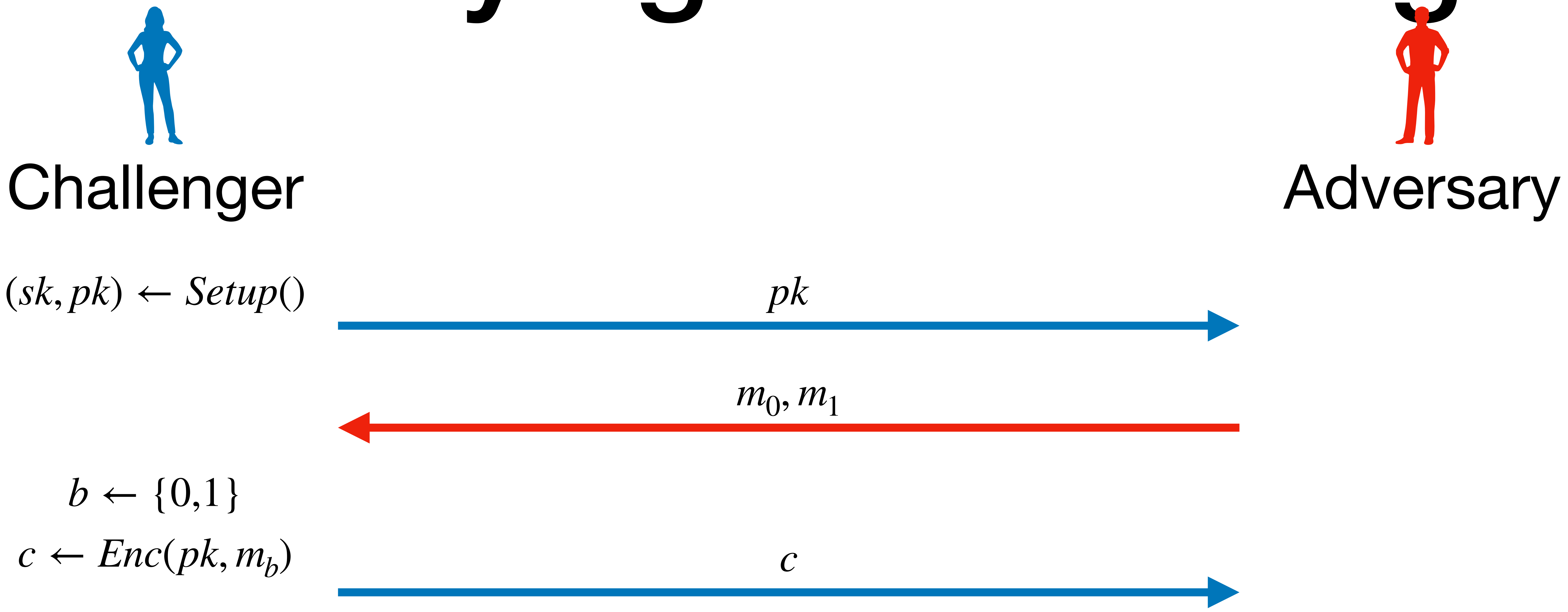

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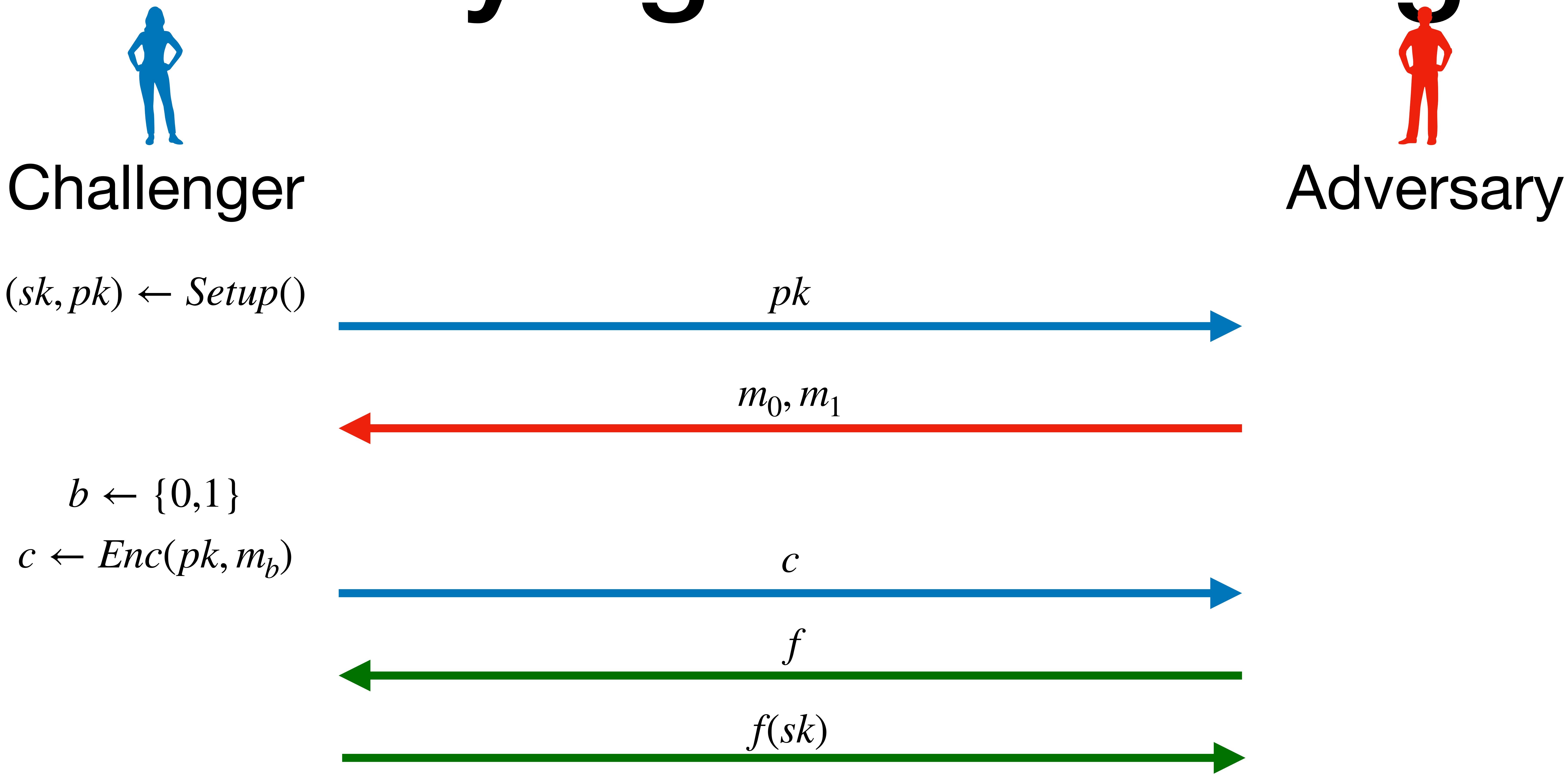

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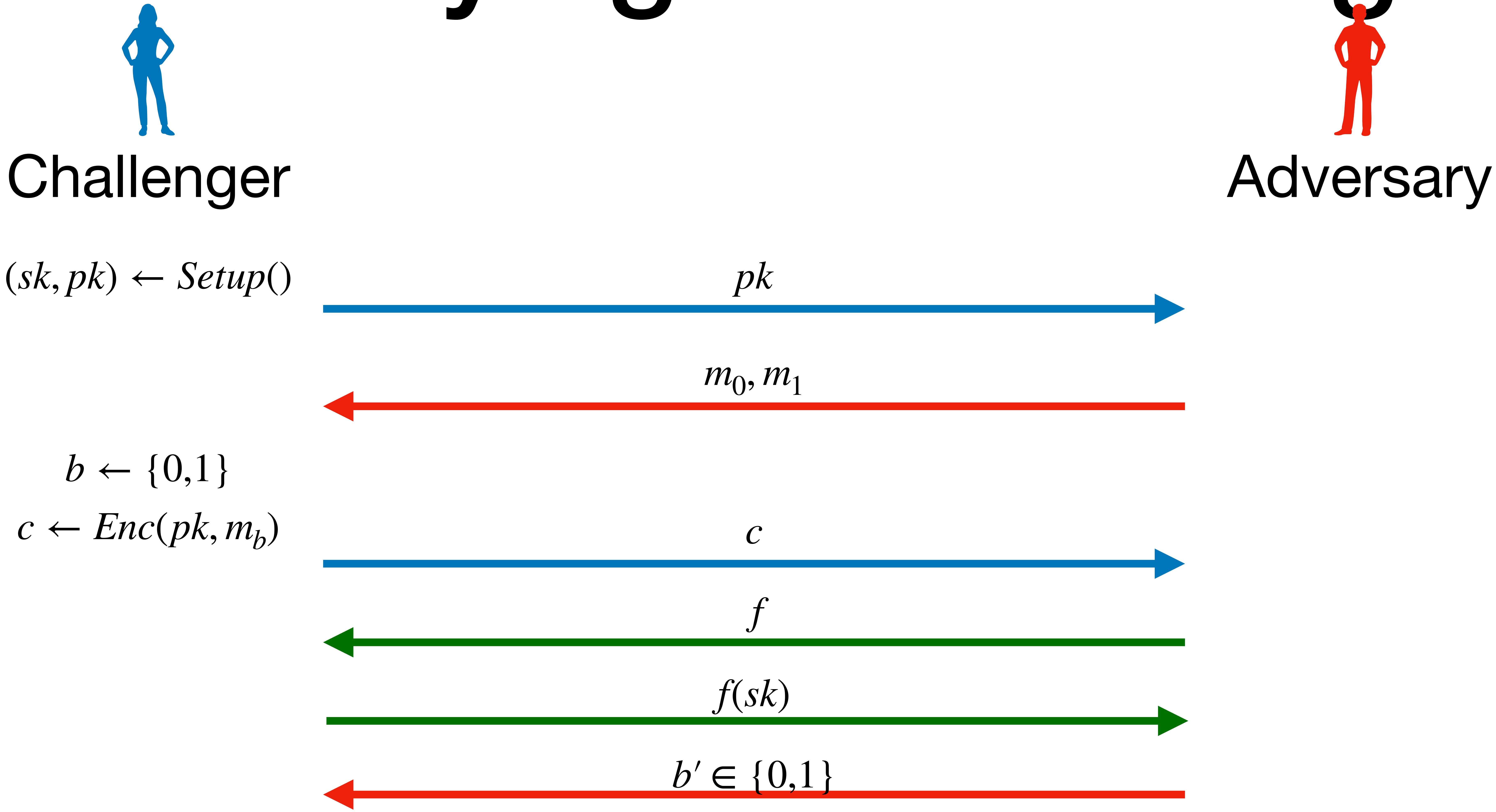
f

$f(sk)$

Security against Leakage



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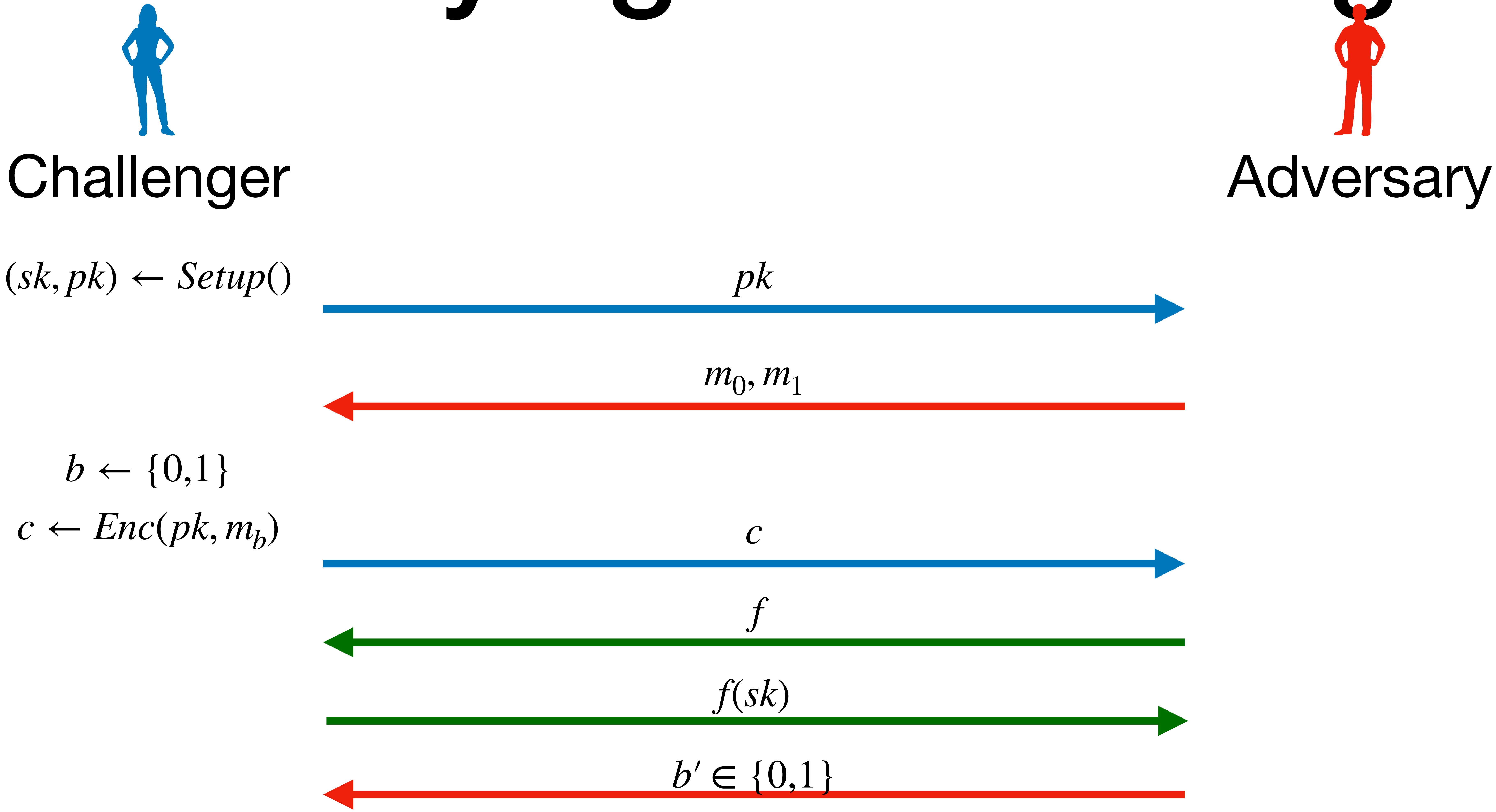

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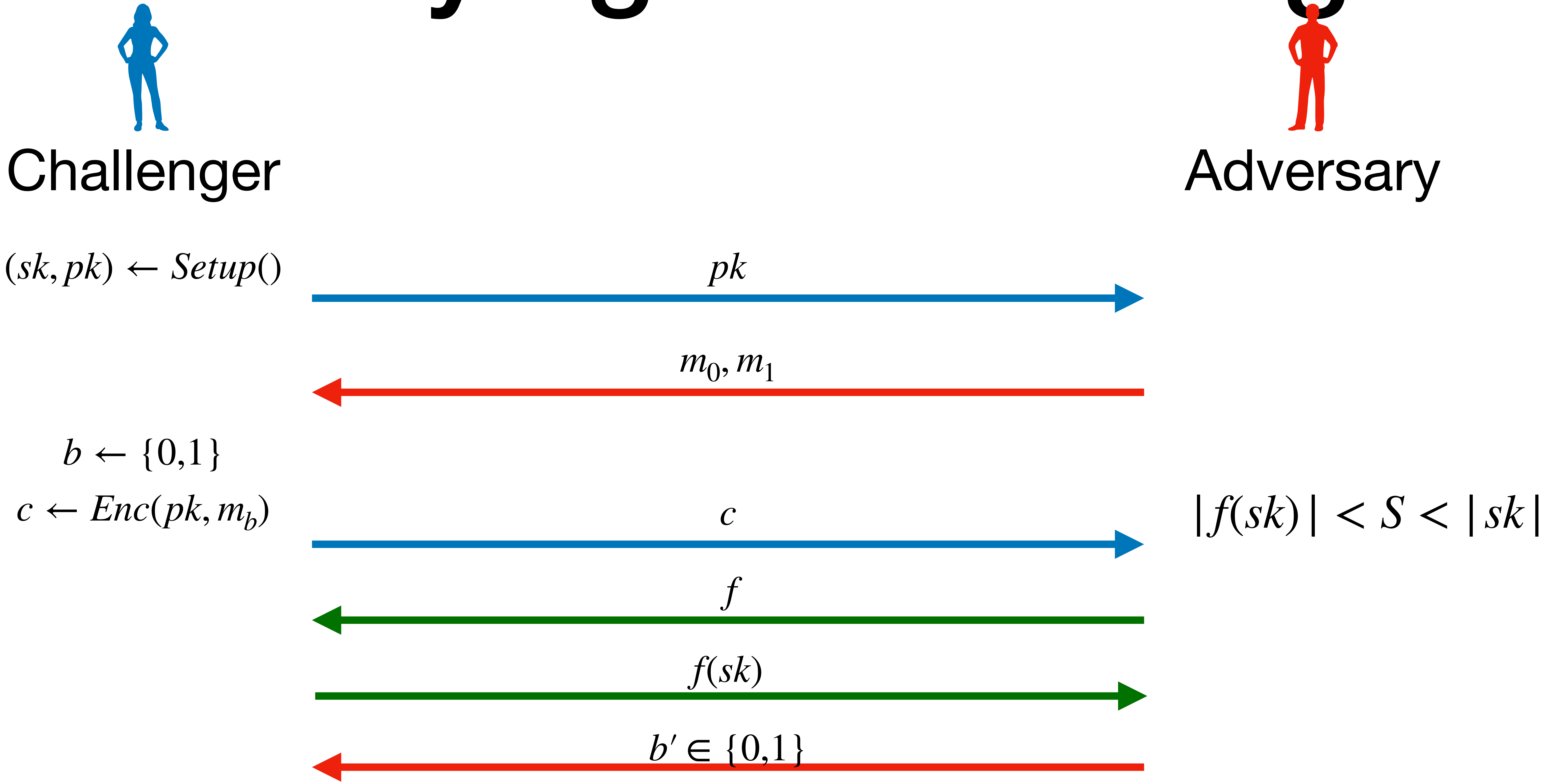

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c →

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

← f

$f(sk)$ →

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- [Dziembowski06], [Di Crescenzo et al.06], [Akavia et al.09], etc. considered arbitrary function f.

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

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- Does not make sense if entire secret key and ciphertext is given to adversary.

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- May be possible for adversary to attain the entire secret key but store only a part of the ciphertext. For example, cloud storage.

Incompressible (PKE) Security

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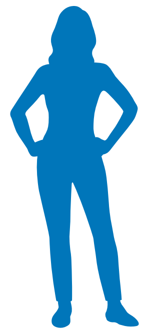
Challenger

Adversary 1

Incompressible (PKE) Security



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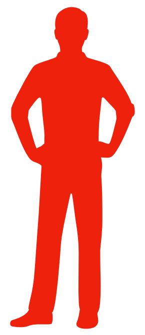
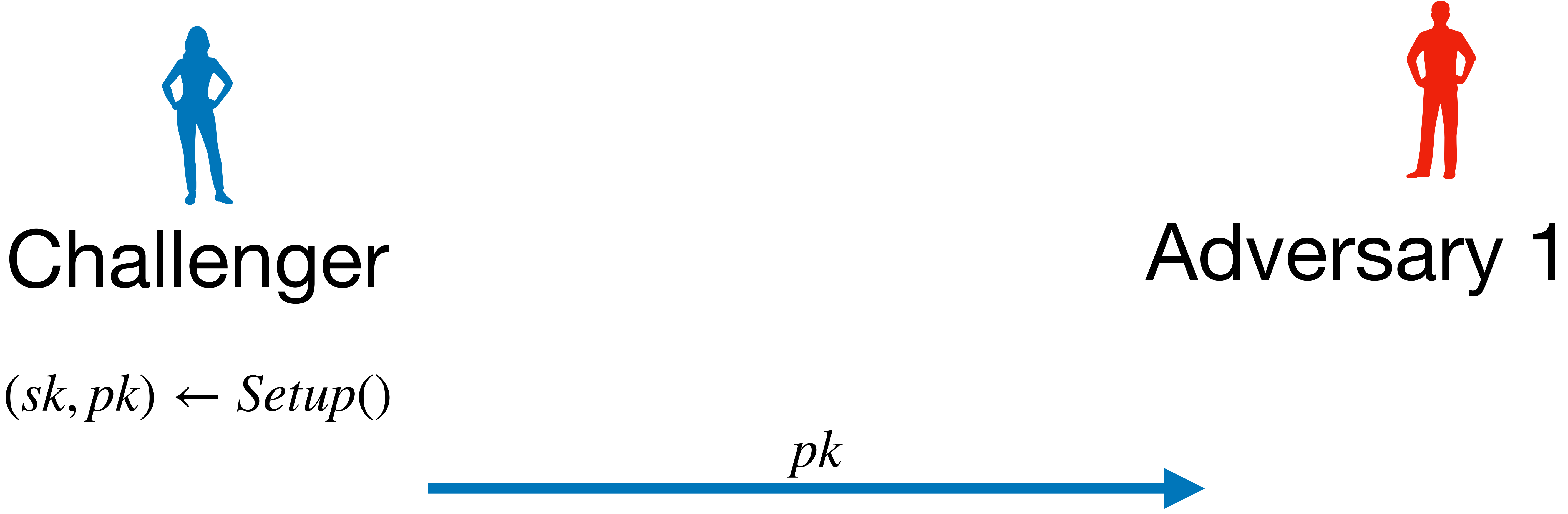


Adversary 1

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

Incompressible (PKE) Security



Challenger

Adversary 1

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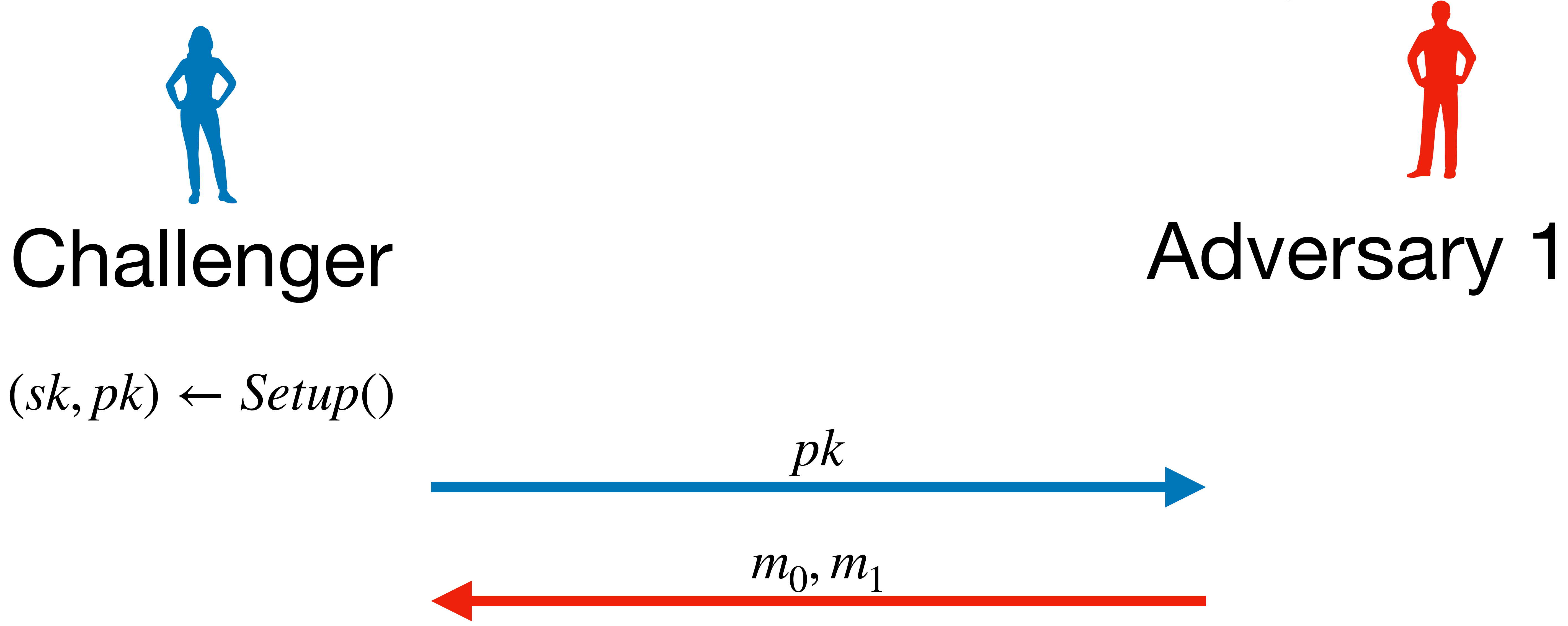
$$\xrightarrow{pk}$$

Incompressible (PKE) Security



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m_0, m_1

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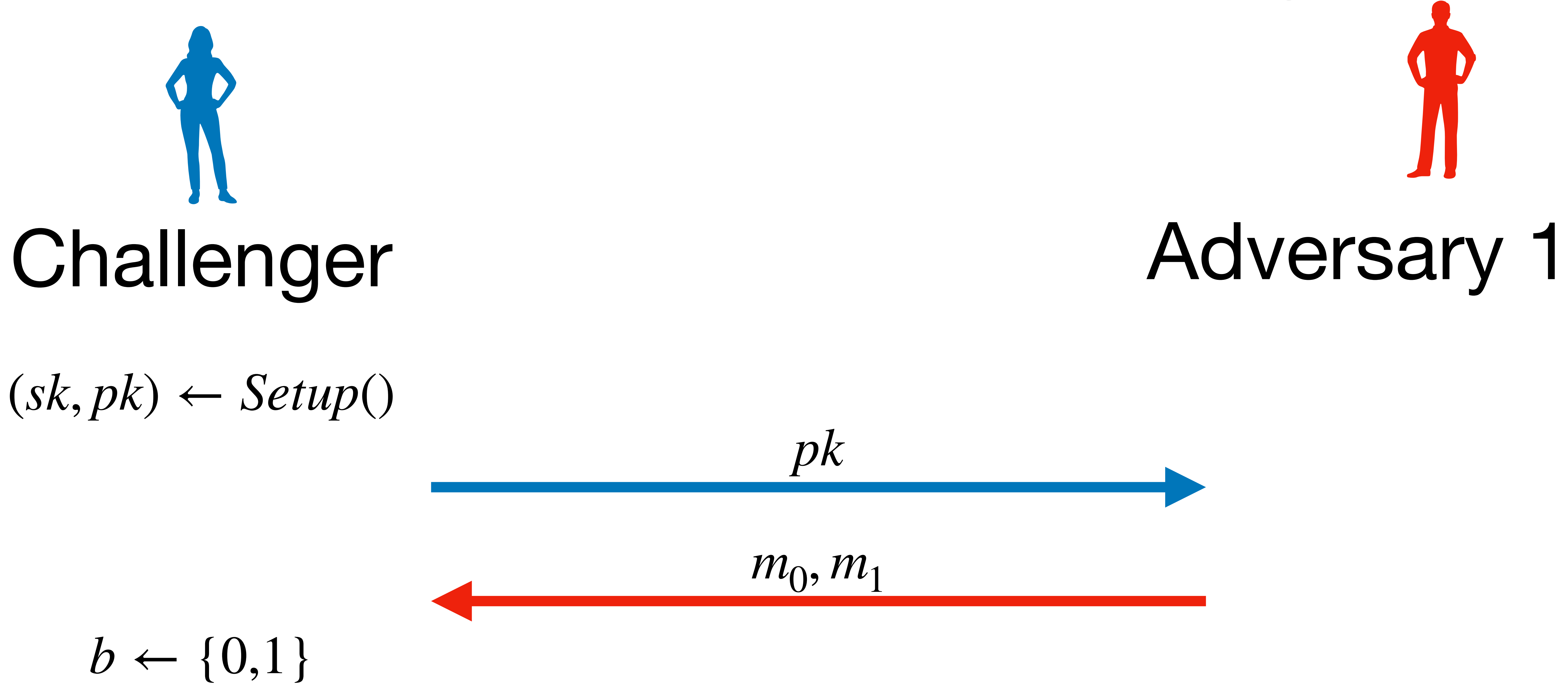

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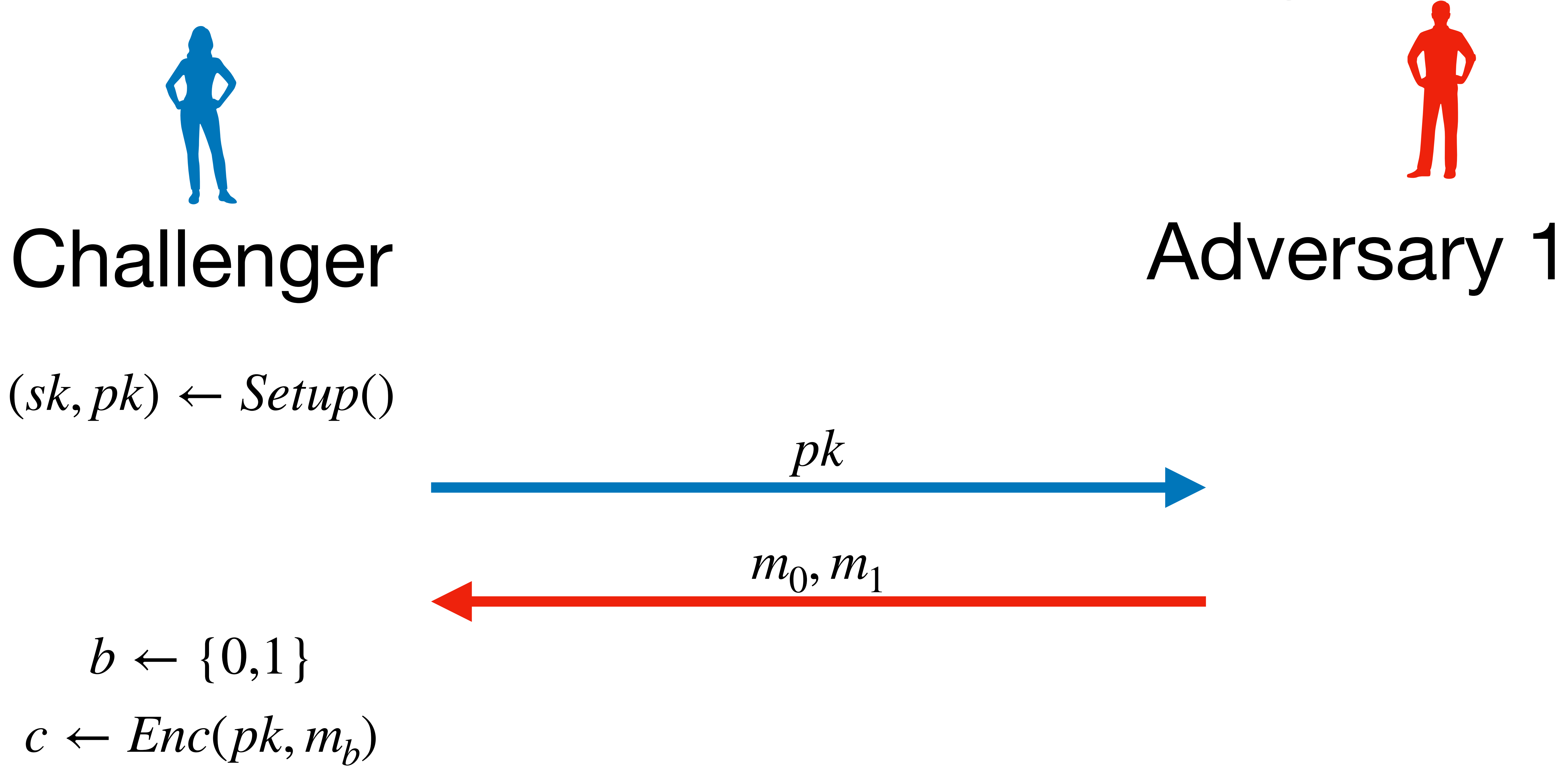

Challenger

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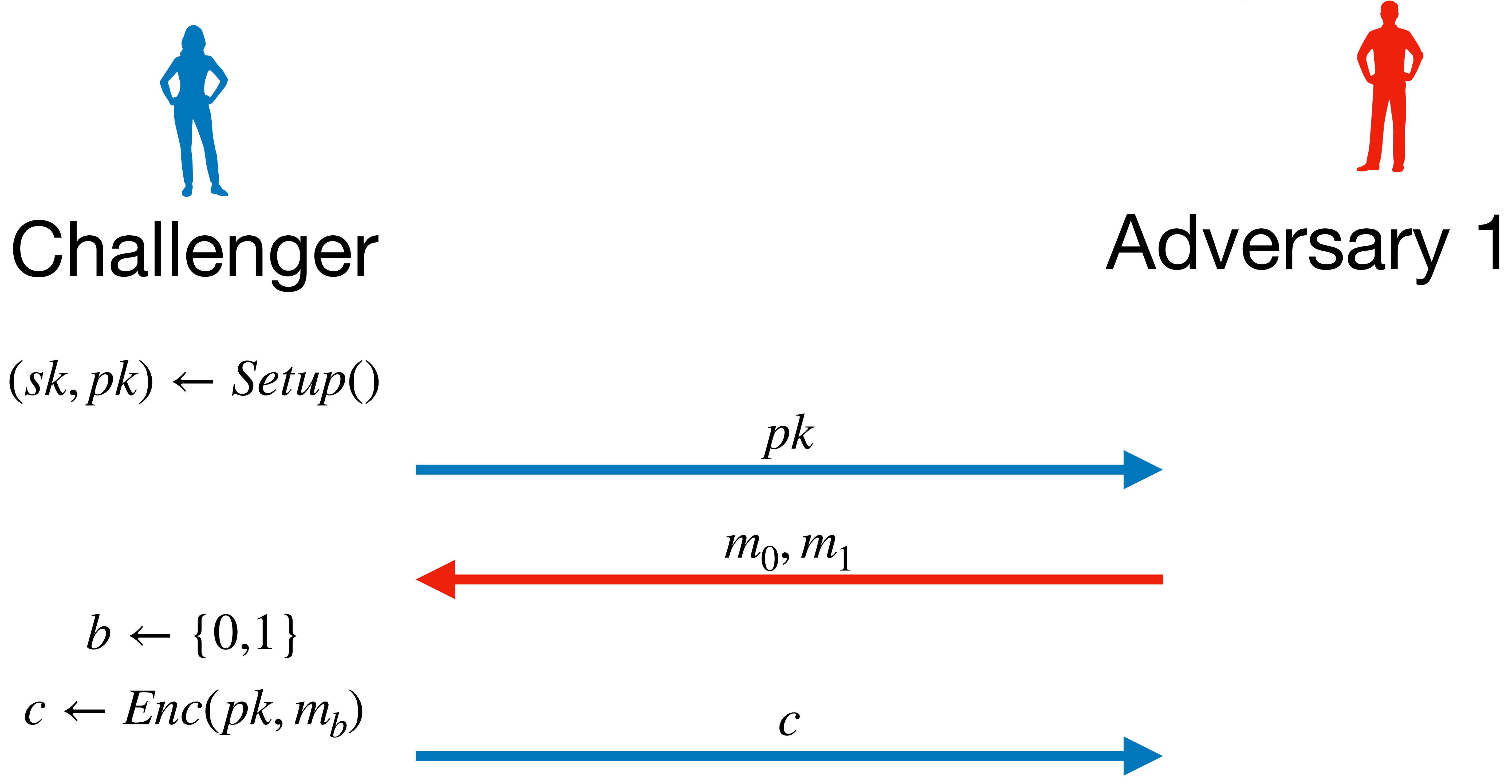

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$(sk, pk) \leftarrow Setup()$

pk $\longrightarrow$

m_0, m_1 $\longleftarrow$

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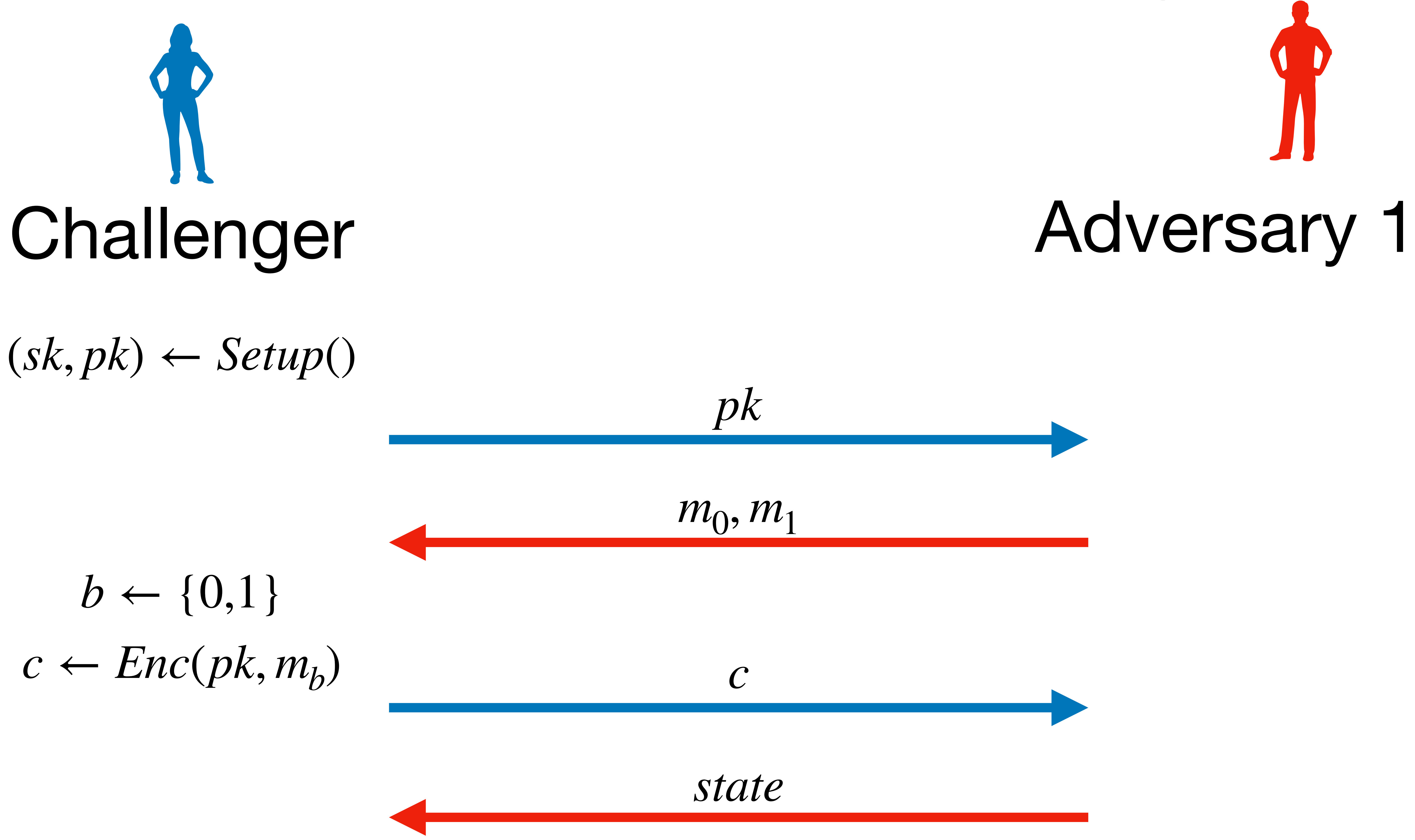
c $\longrightarrow$

Incompressible (PKE) Security



Challenger

Adversary 1

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

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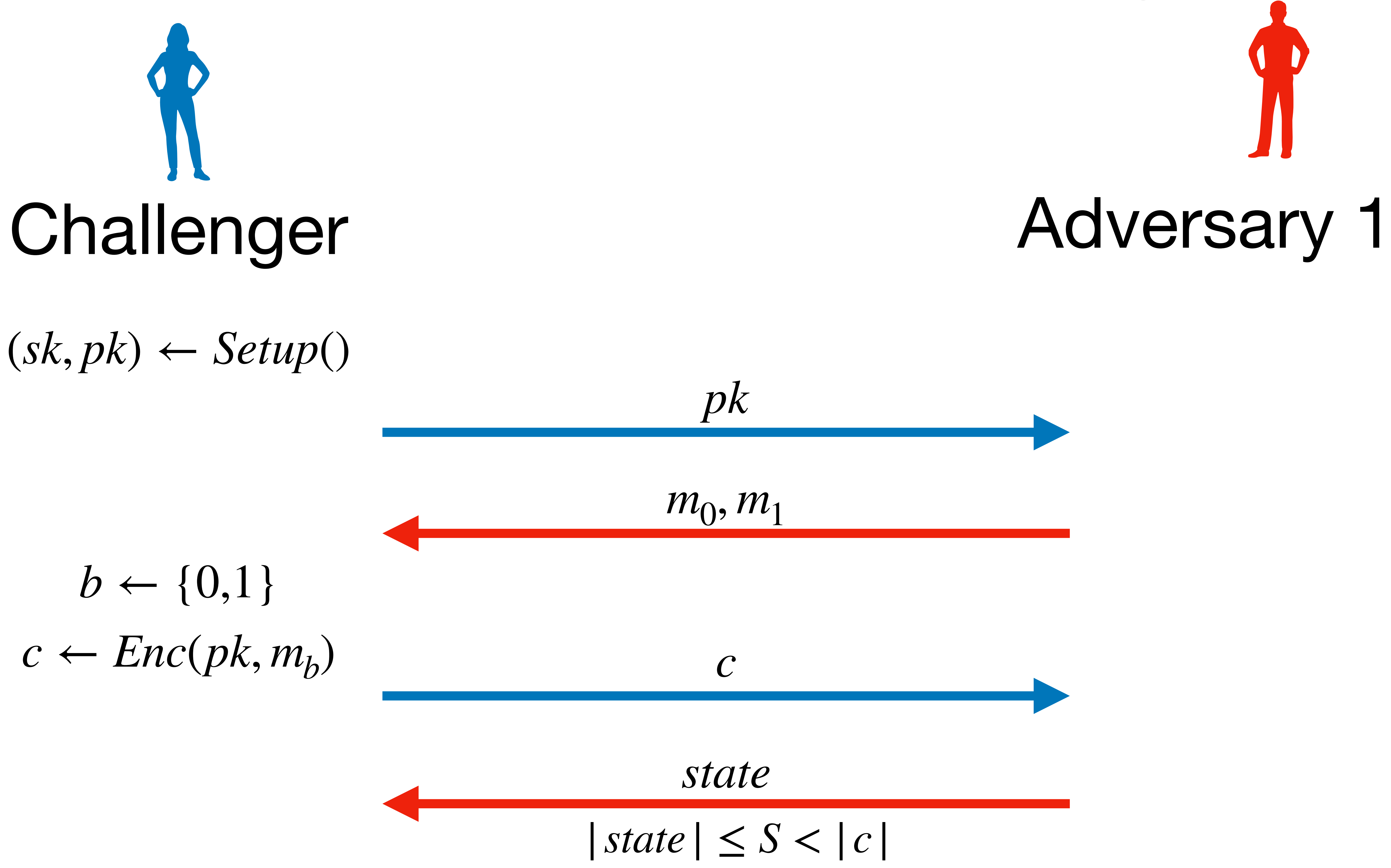
Incompressible (PKE) Security



Challenger

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m_0, m_1

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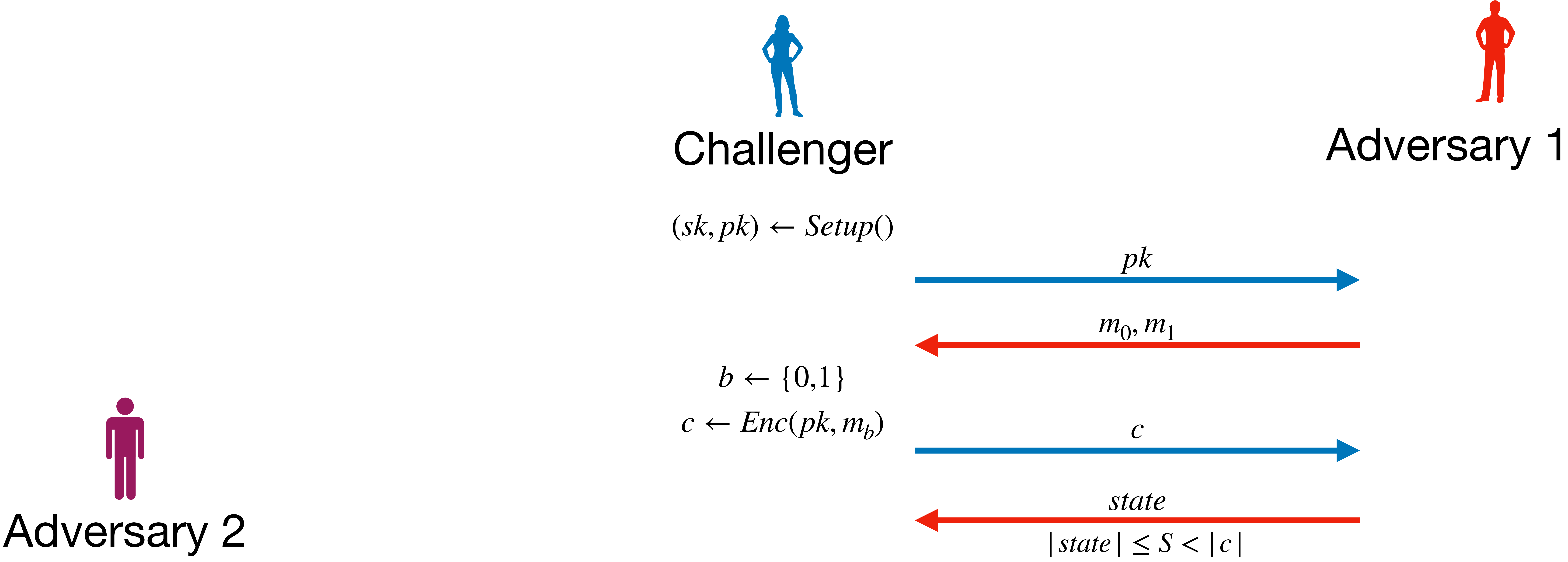
c

$state$

$|state| \leq S < |c|$

Incompressible (PKE) Security



Challenger

Adversary 1

Adversary 2

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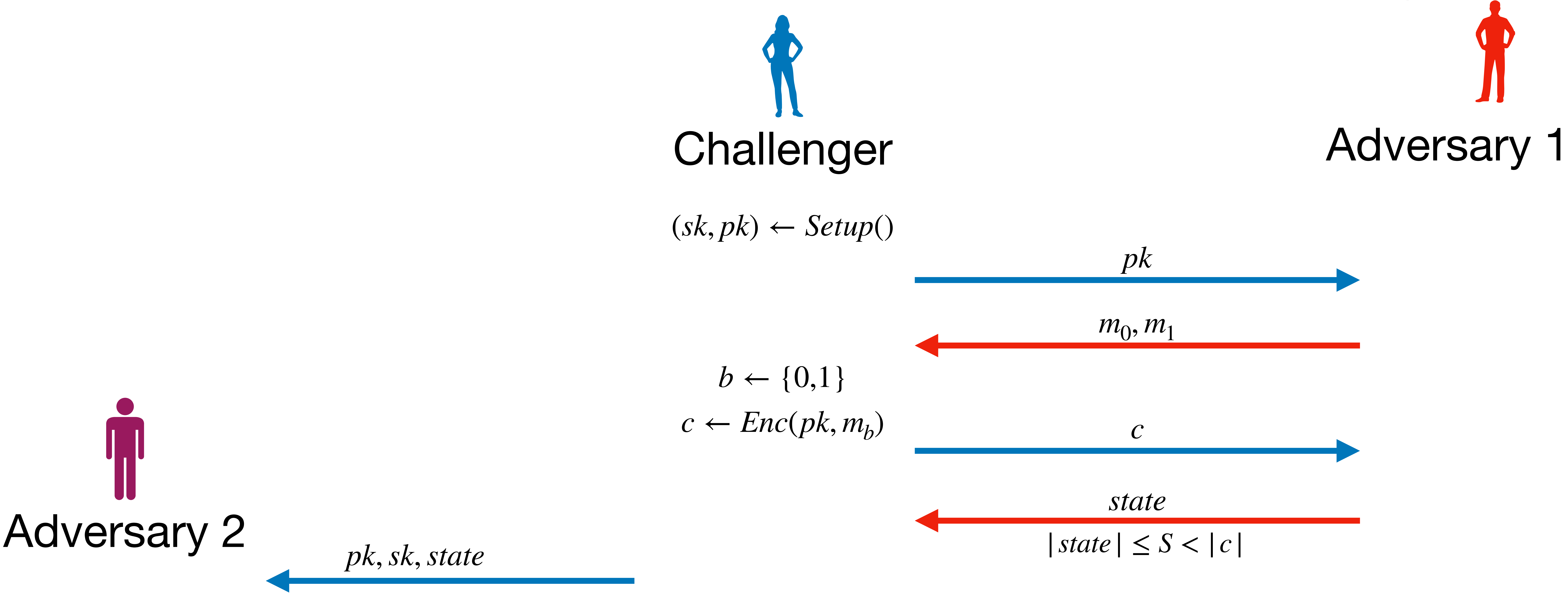
Incompressible (PKE) Security



Challenger

Adversary 1

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c

$state$

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$pk, sk, state$

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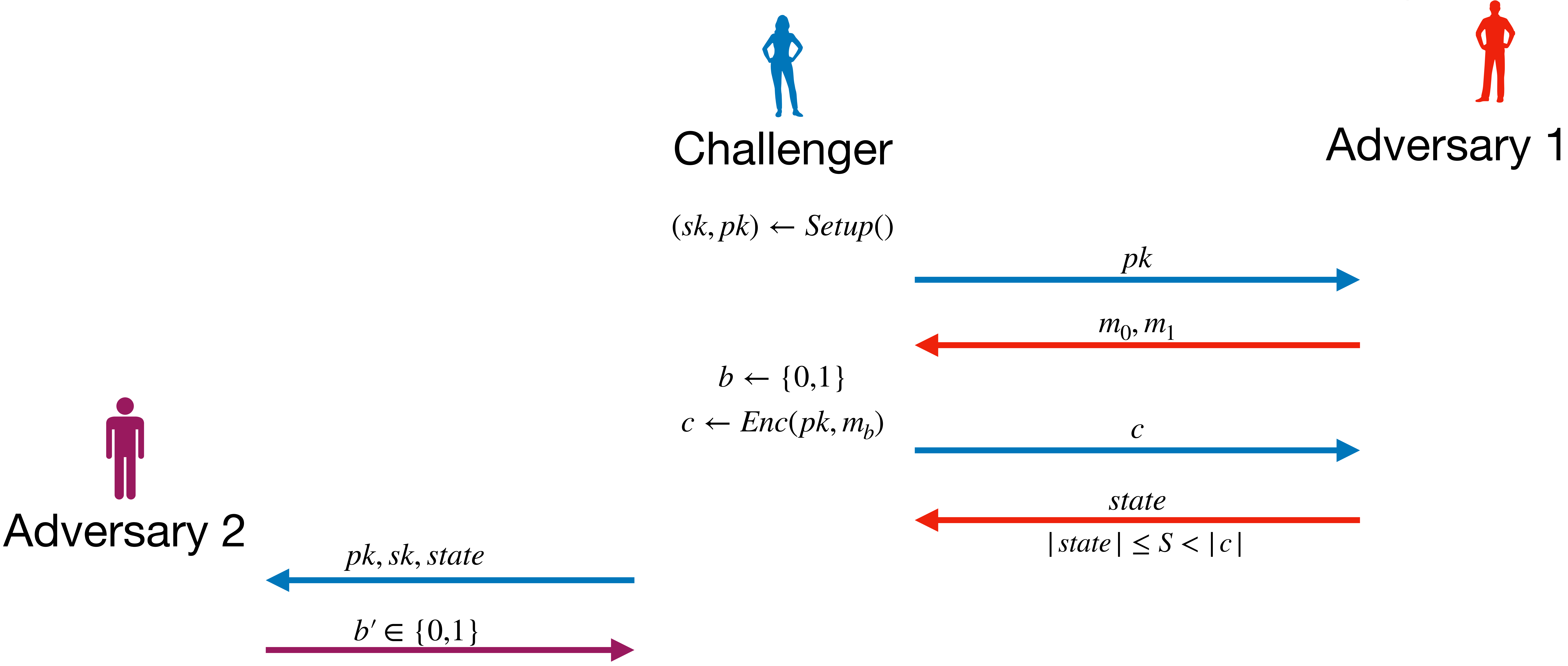

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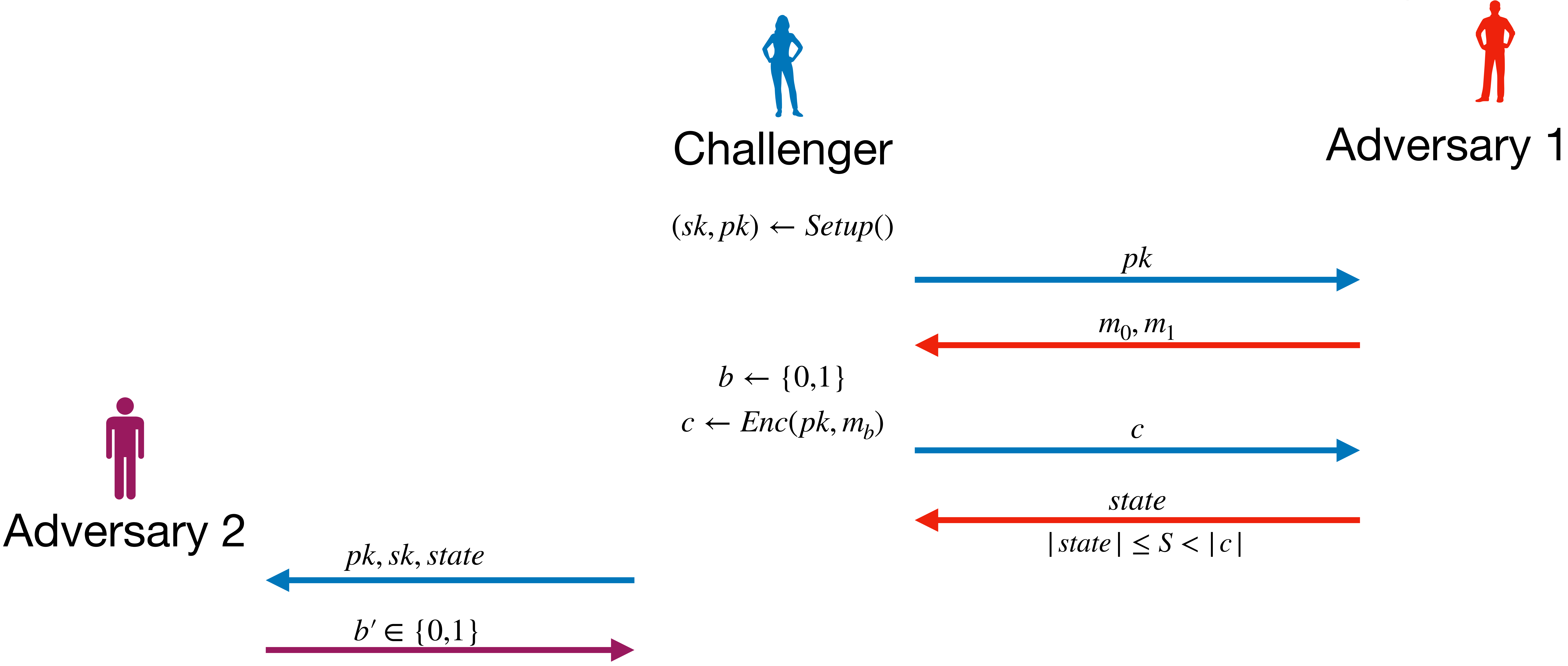

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Adversaries wins if $b = b'$

Incompressible SKE Schemes

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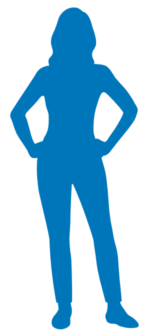
- Branco et al. gave a construction based on hardness of LWE and DDH which is rate 1.
- Our Result : a generic transformation from PKE to incompressible PKE. This also works for more advanced notions of encryption.

Incompressible SKE & PKE

Incompressible (SKE) Security

Incompressible (SKE) Security

Incompressible (SKE) Security



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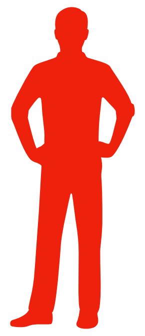

Adversary 1

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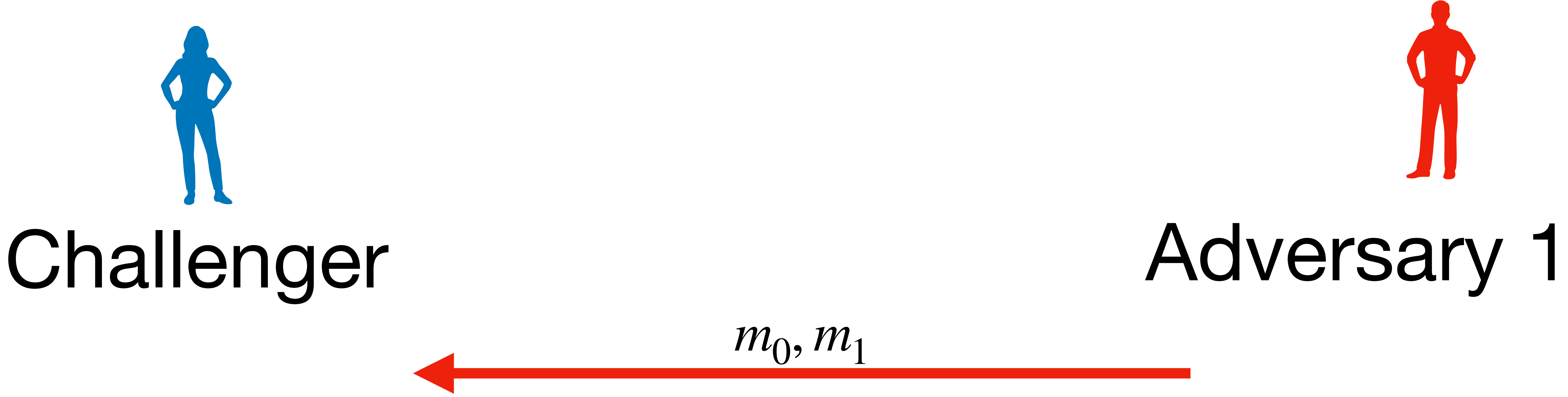
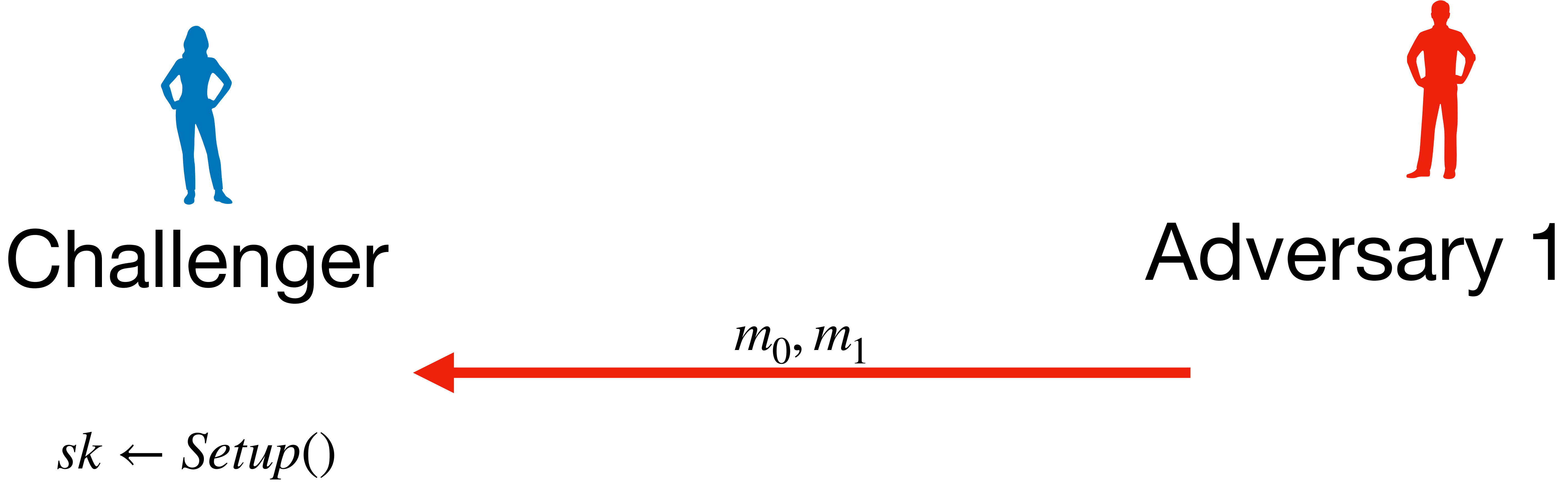


Challenger

Adversary 1

m_0, m_1

Incompressible (SKE) Security



Challenger

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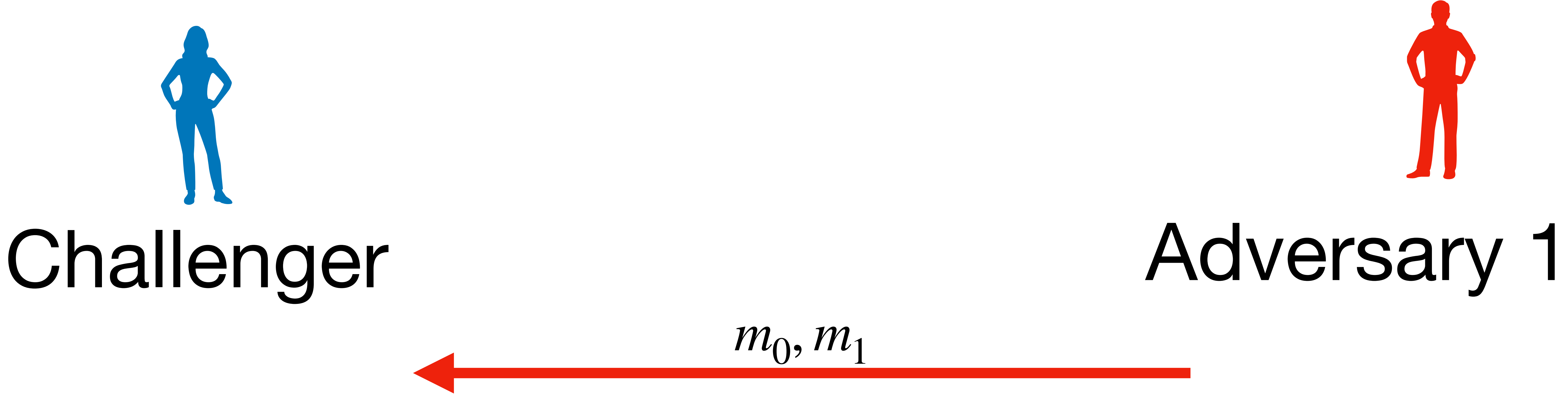
Incompressible (SKE) Security



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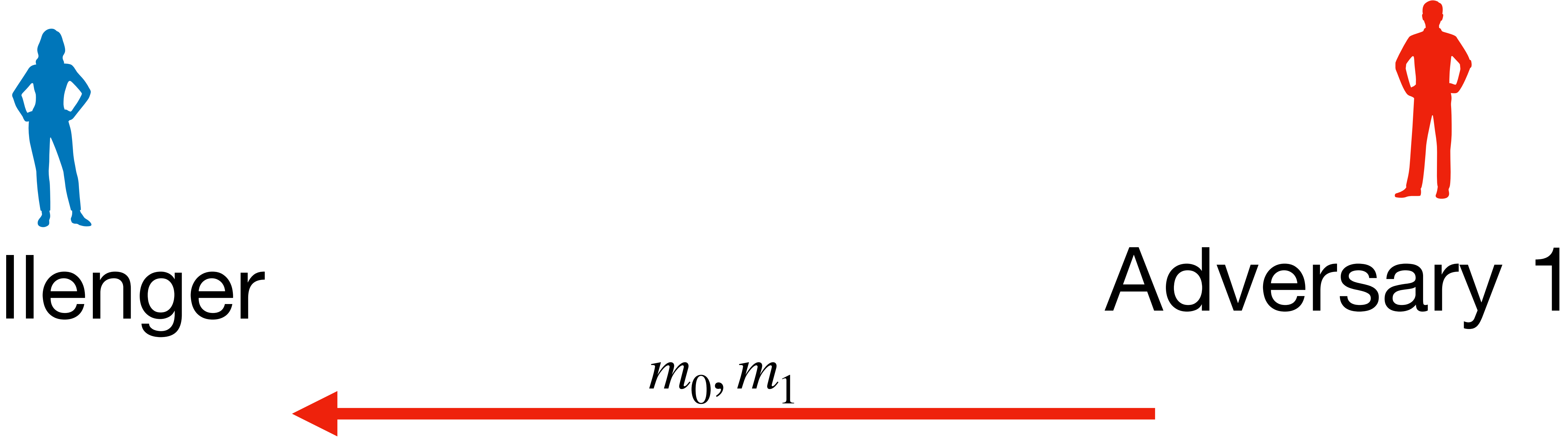
Incompressible (SKE) Security



Challenger

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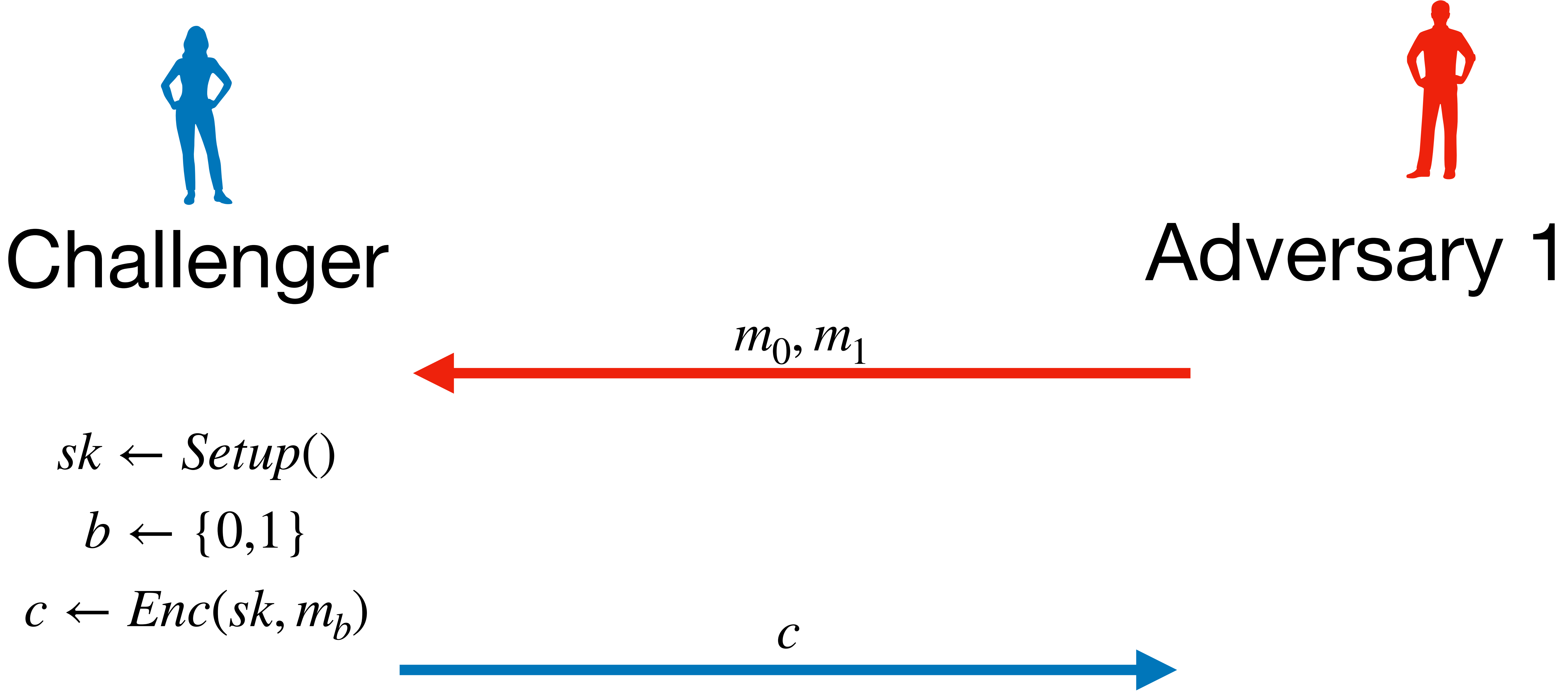

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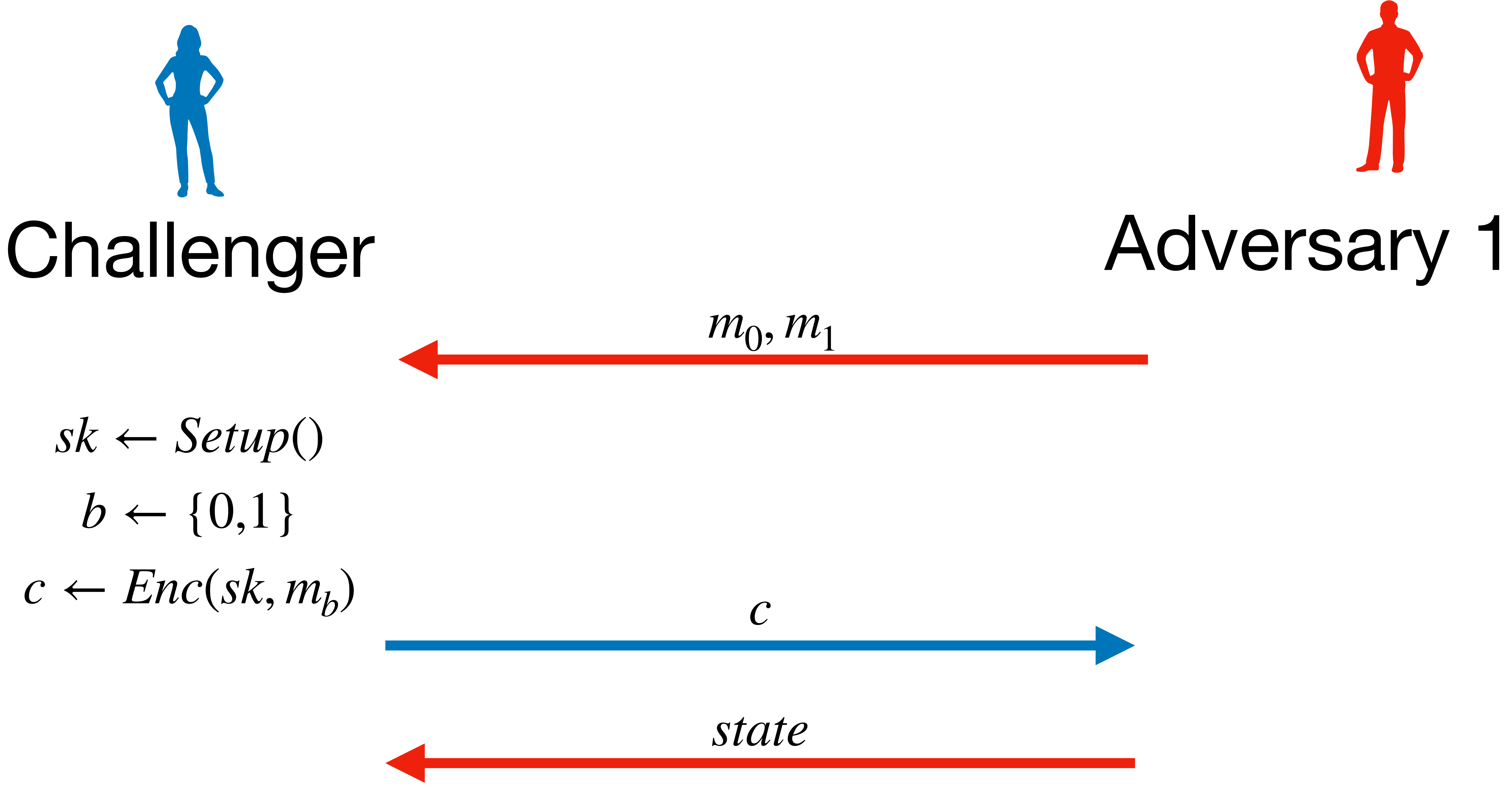

Challenger

Adversary 1

m_0, m_1

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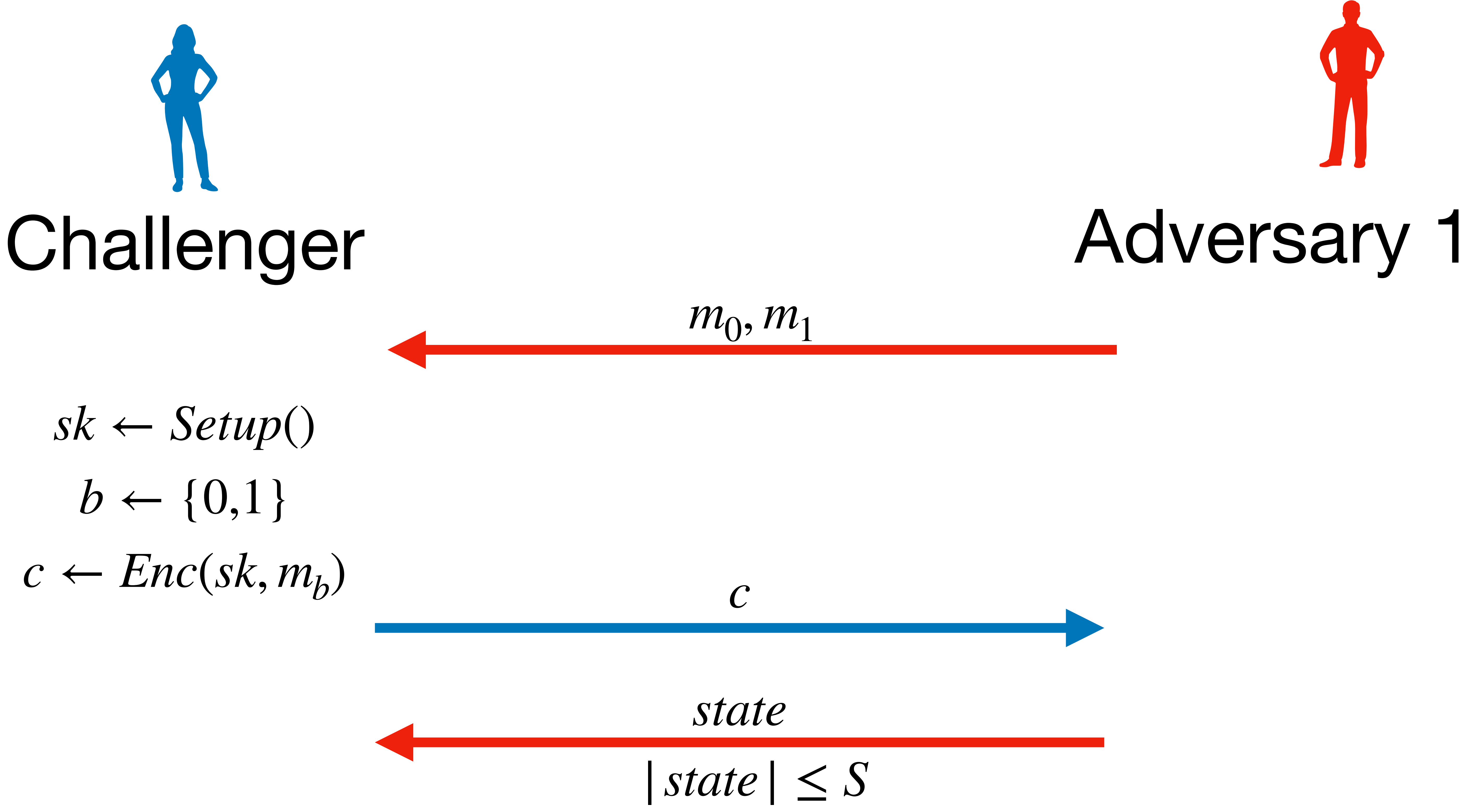
c

$state$

Incompressible (SKE) Security



Challenger

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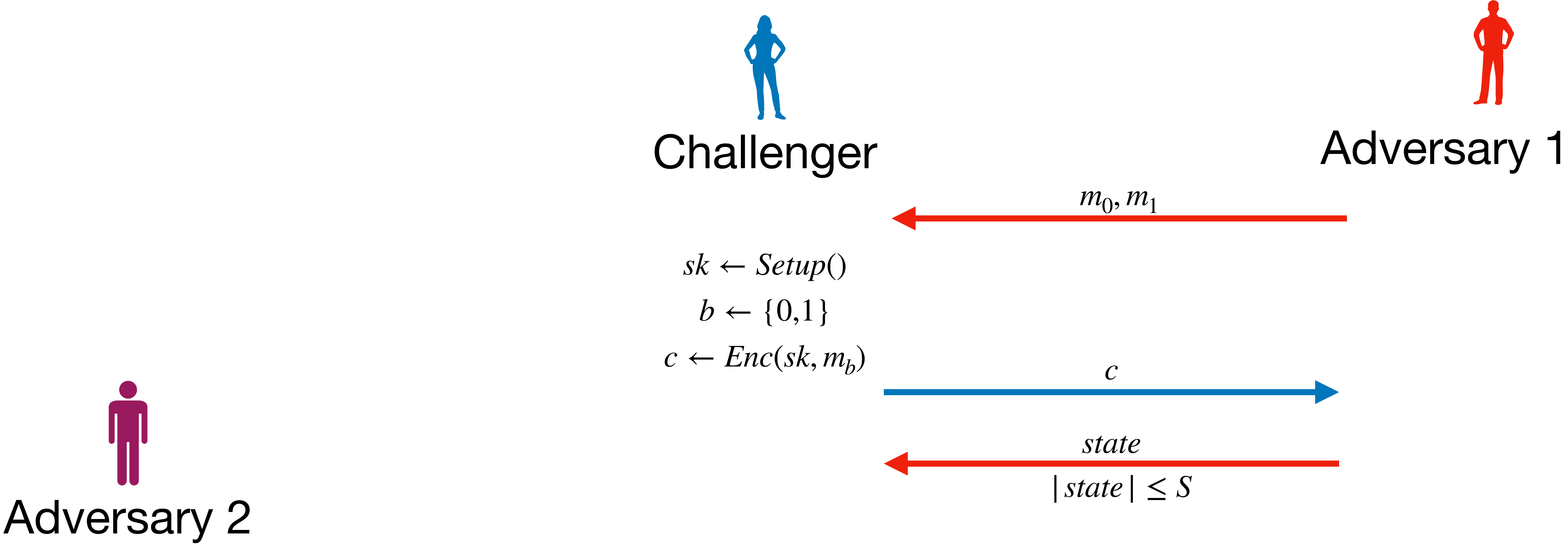
Incompressible (SKE) Security



Challenger

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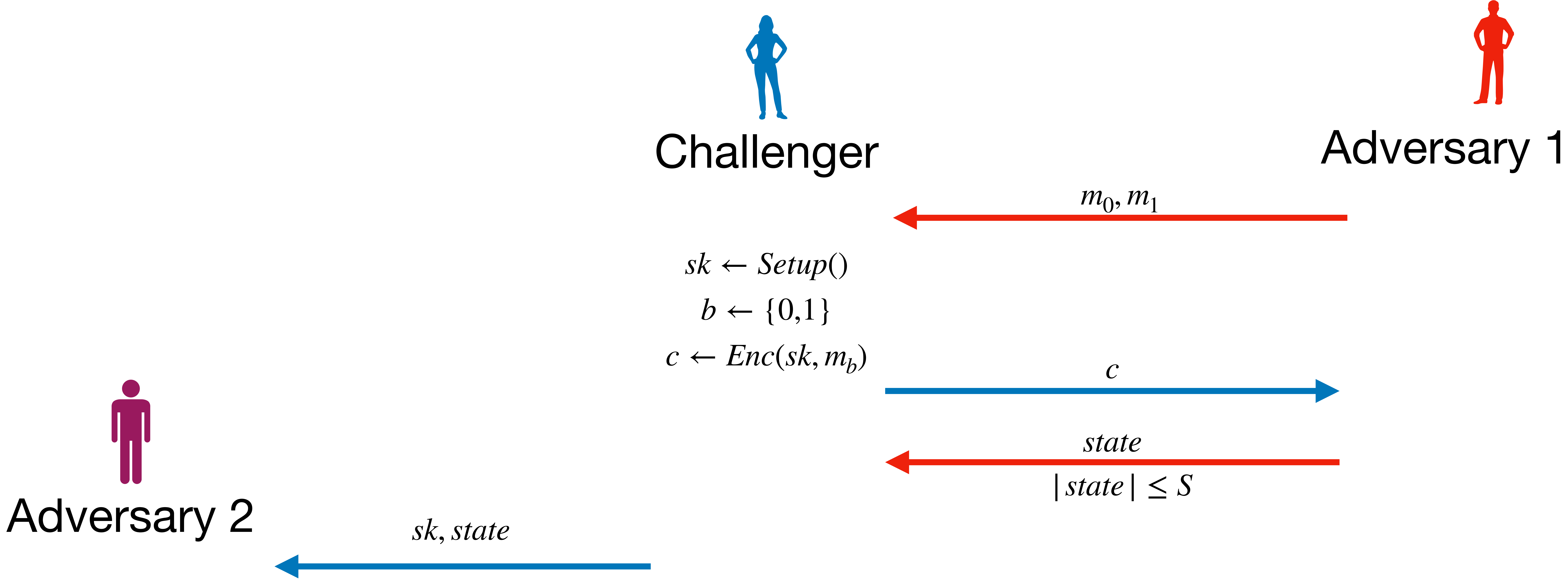
Adversary 2

Incompressible (SKE) Security



Challenger

Adversary 1

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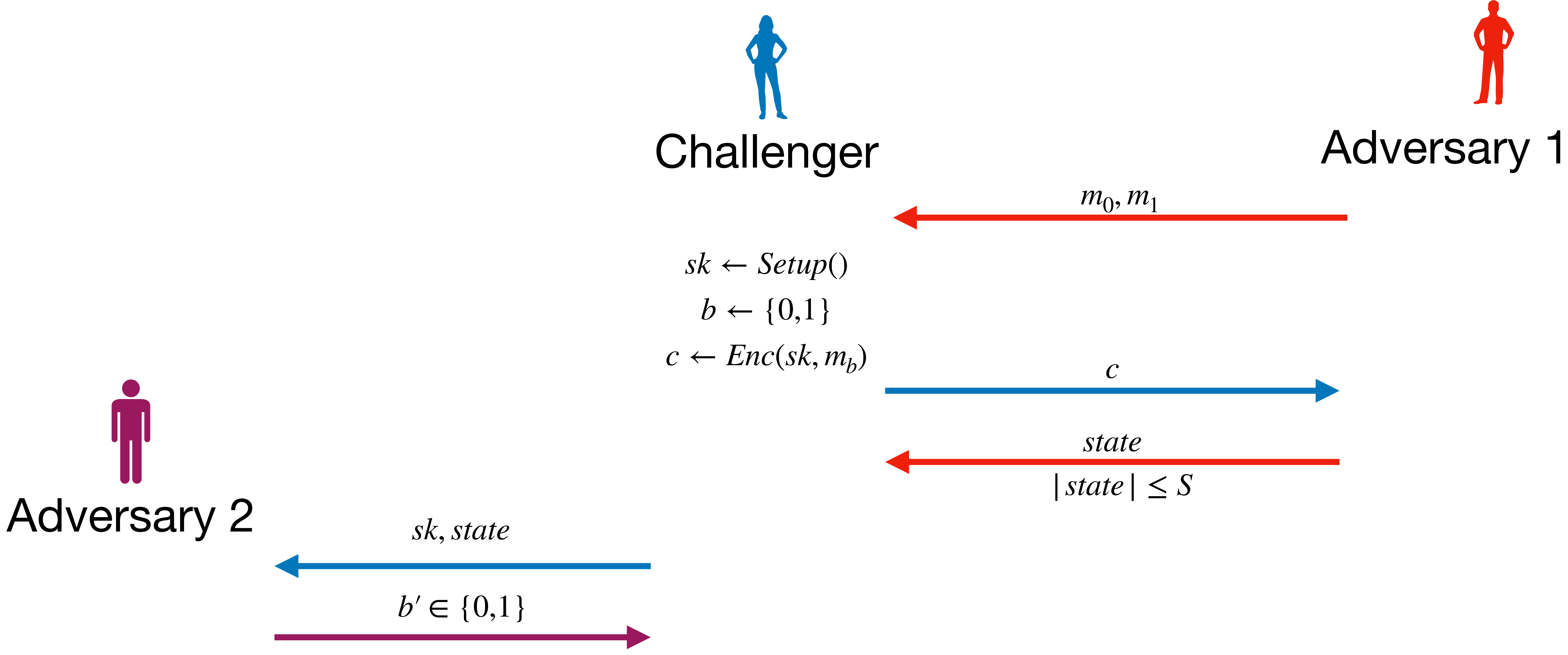
Adversary 2

$sk, state$

Incompressible (SKE) Security



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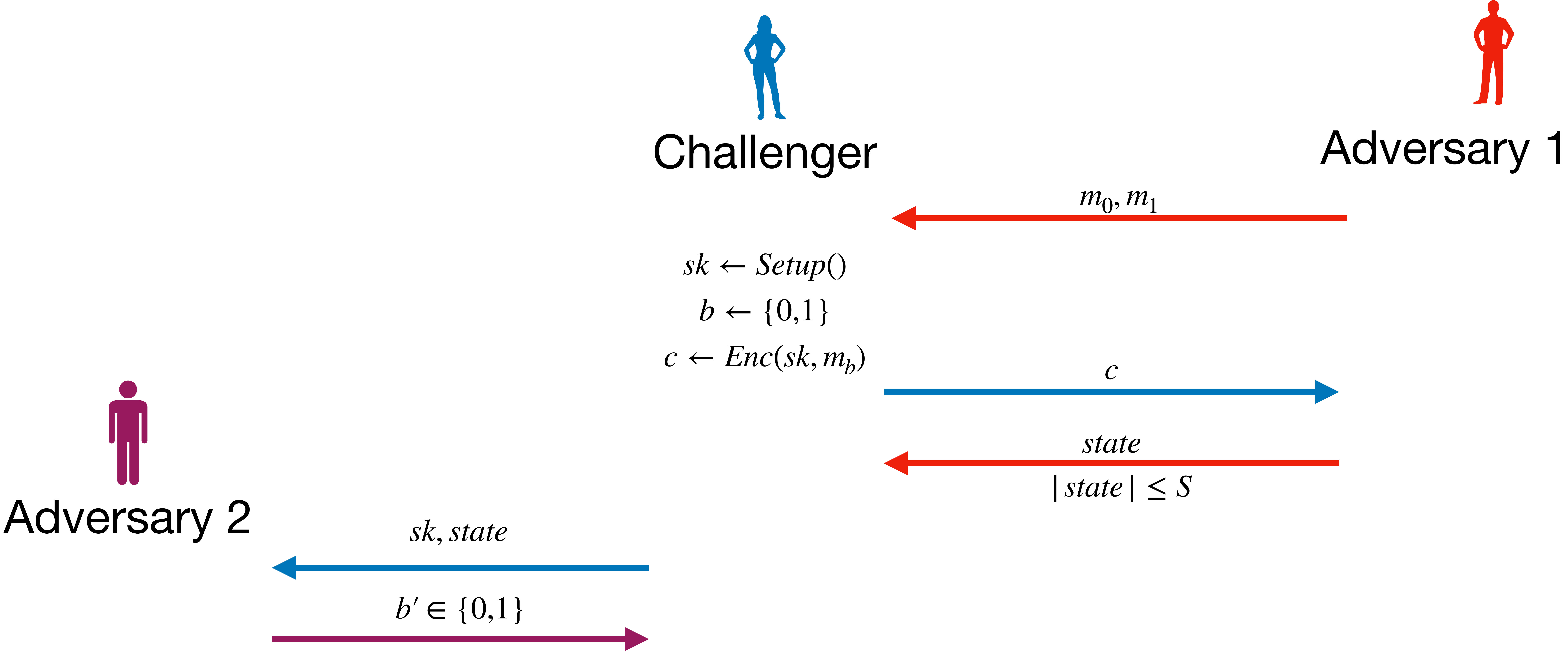

Challenger

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$sk, state$

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One Time Pad is Compressible

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- Consider $m_0 = 0^n$ and $m_1 = 1^n$. After receiving c, the first adversary creates $state = c[0]$.

- Only receiving sk, the second adversary returns $b' = state[0] \oplus sk[0]$.

Incompressible Security

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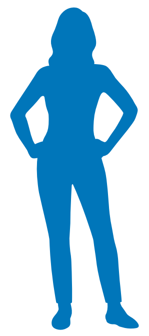

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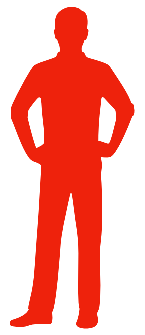
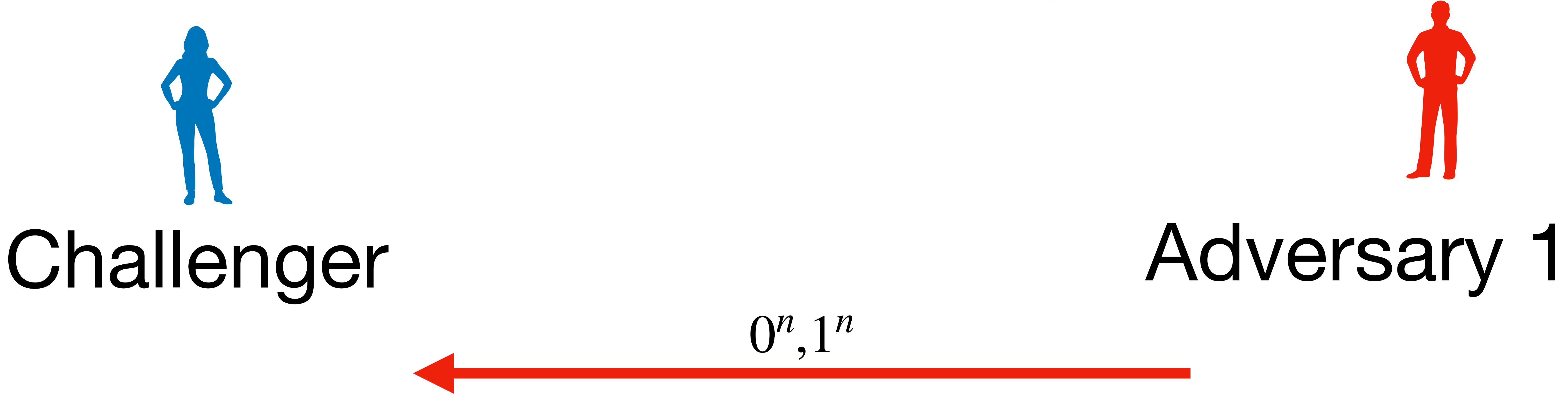


Adversary 1

Incompressible Security

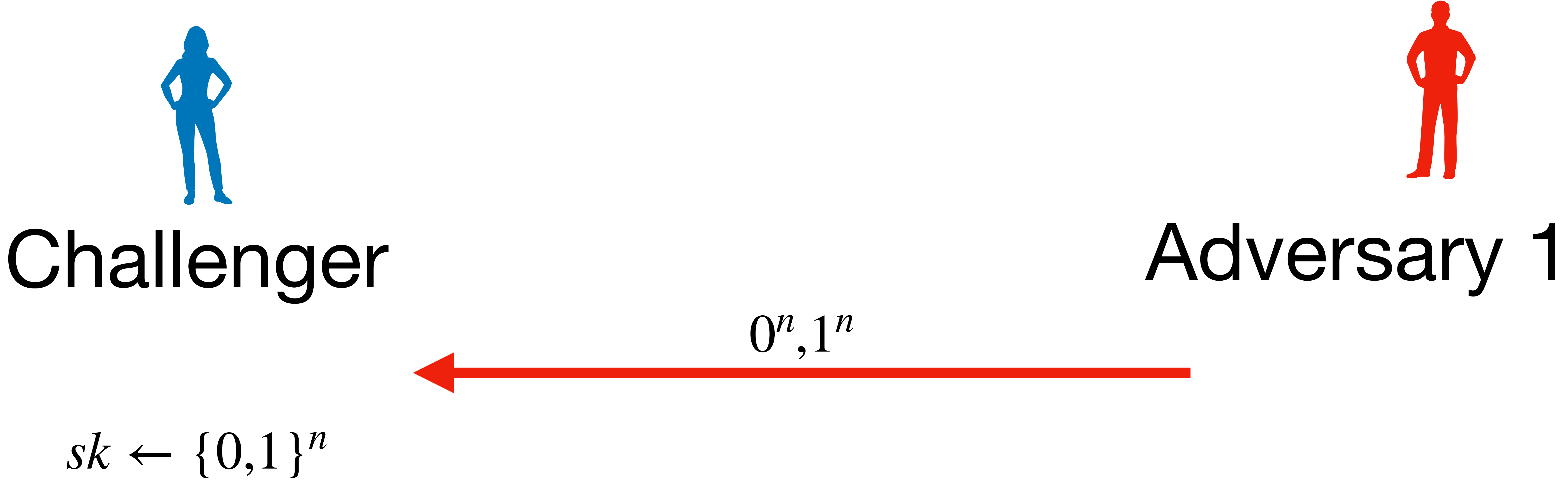


Challenger

Adversary 1

$0^n, 1^n$

Incompressible Security



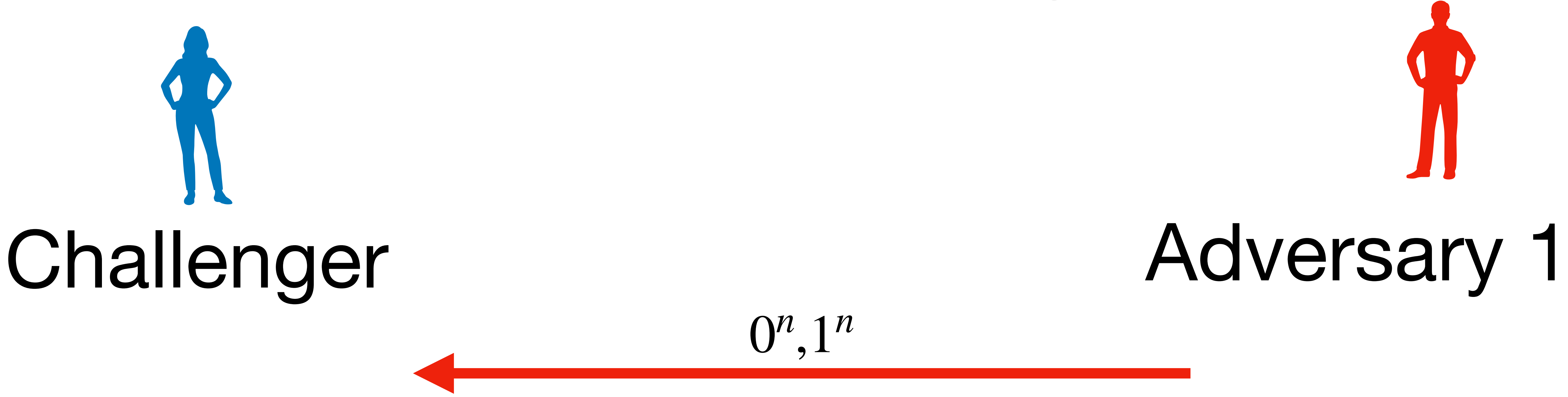
Challenger

Adversary 1

$0^n, 1^n$

$sk \leftarrow \{0,1\}^n$

Incompressible Security



$sk \leftarrow \{0,1\}^n$

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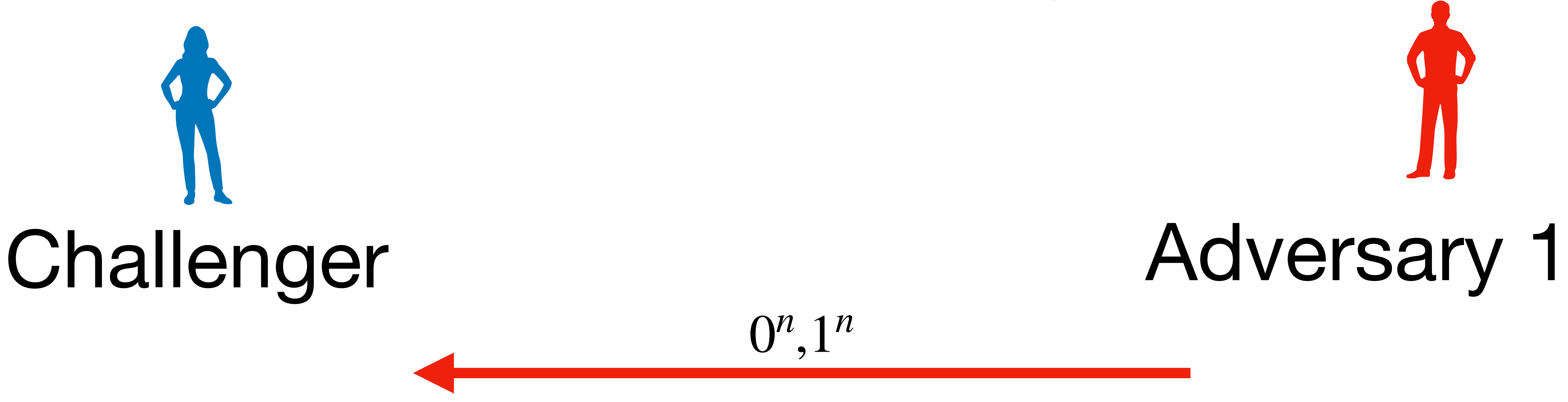
Incompressible Security



$$sk \leftarrow \{0,1\}^n$$

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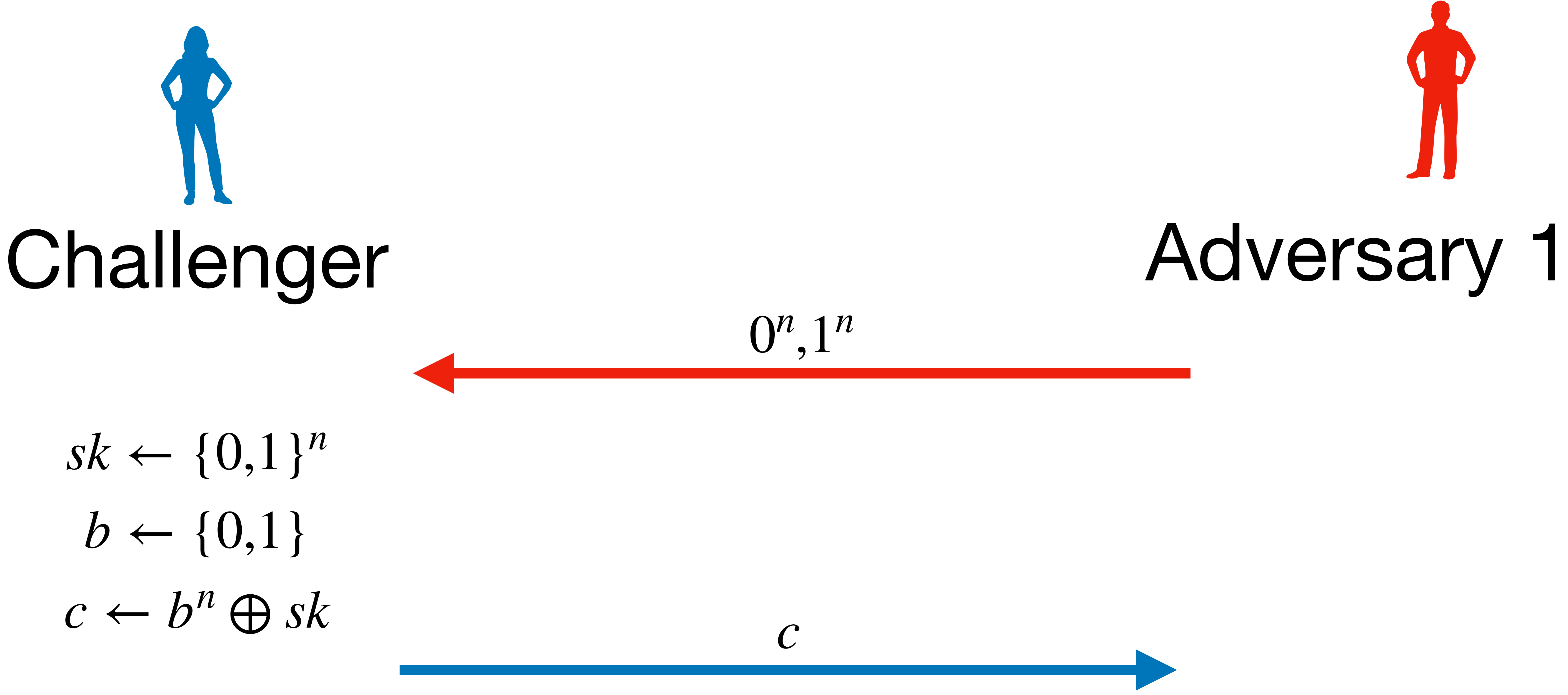
$$c \leftarrow b^n \oplus sk$$

Incompressible Security



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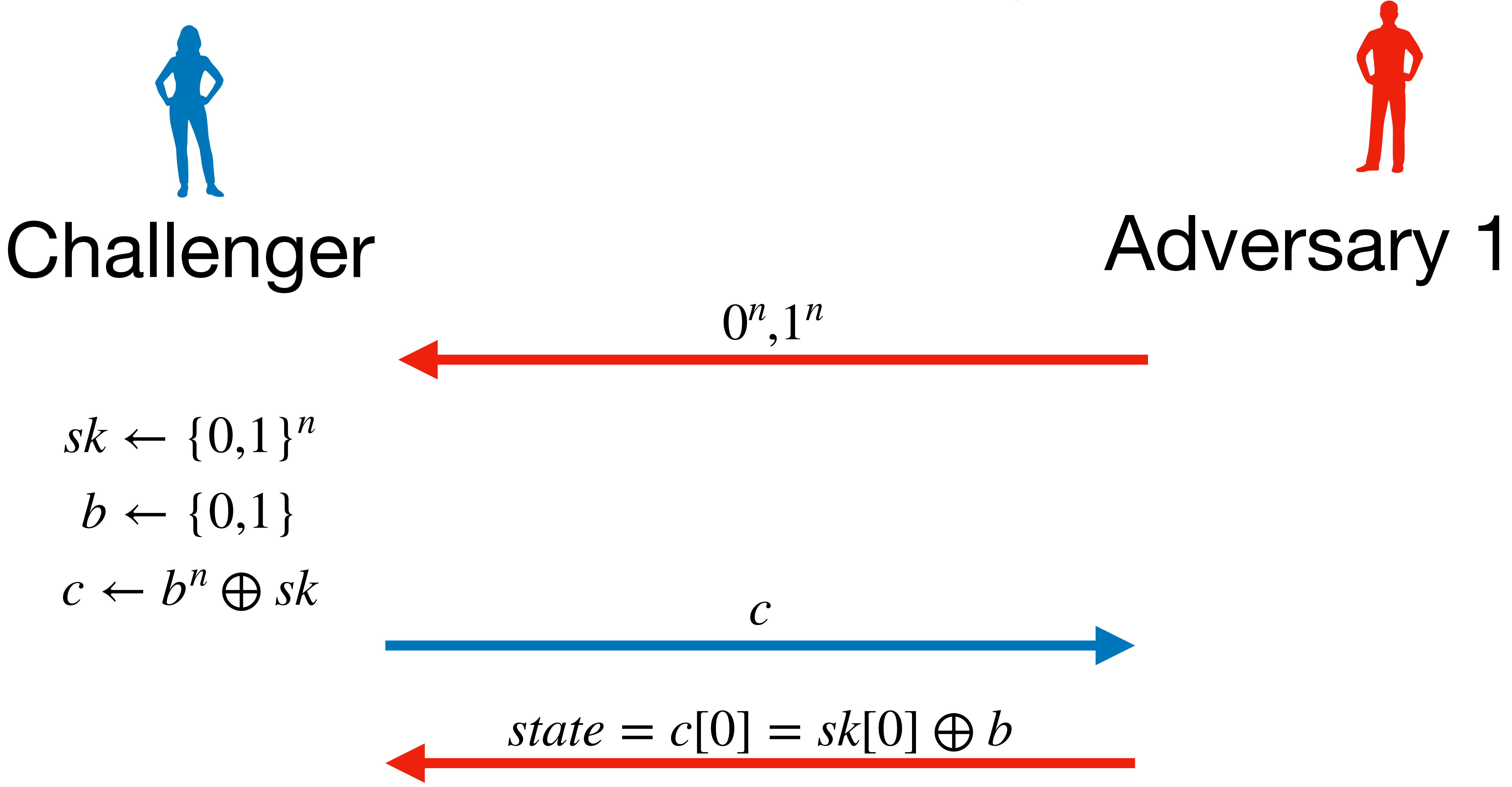

$0^n, 1^n$

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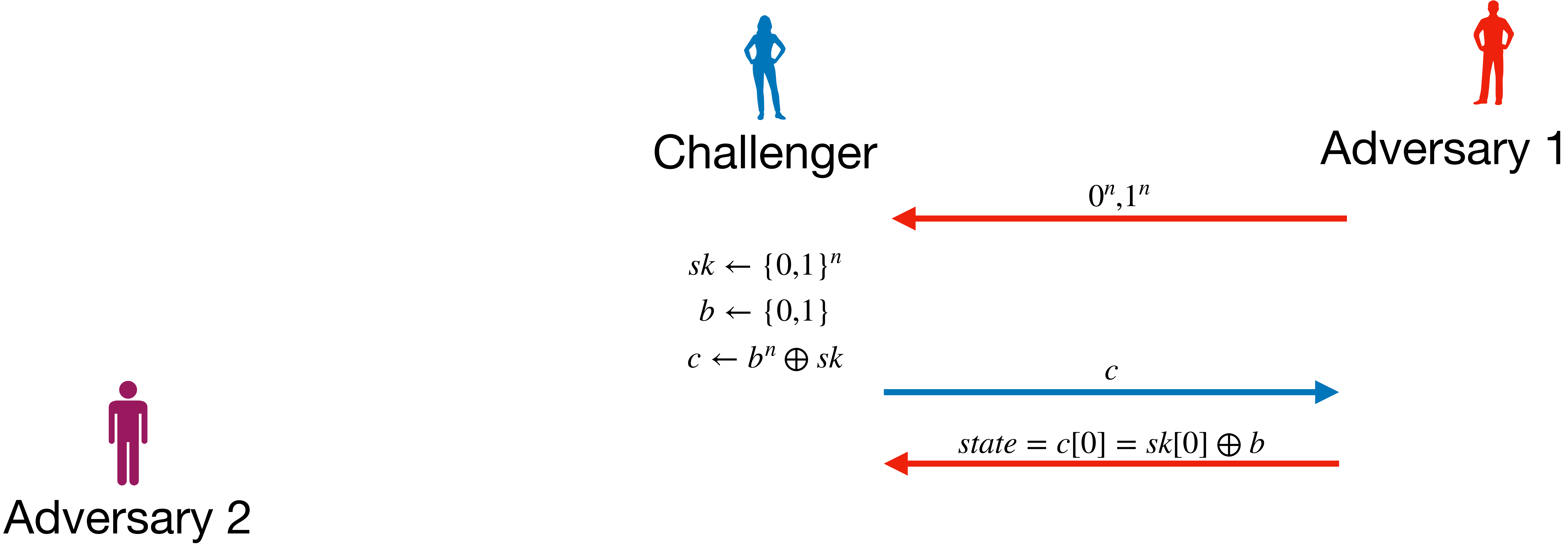
$state = c[0] = sk[0] \oplus b$

Incompressible Security



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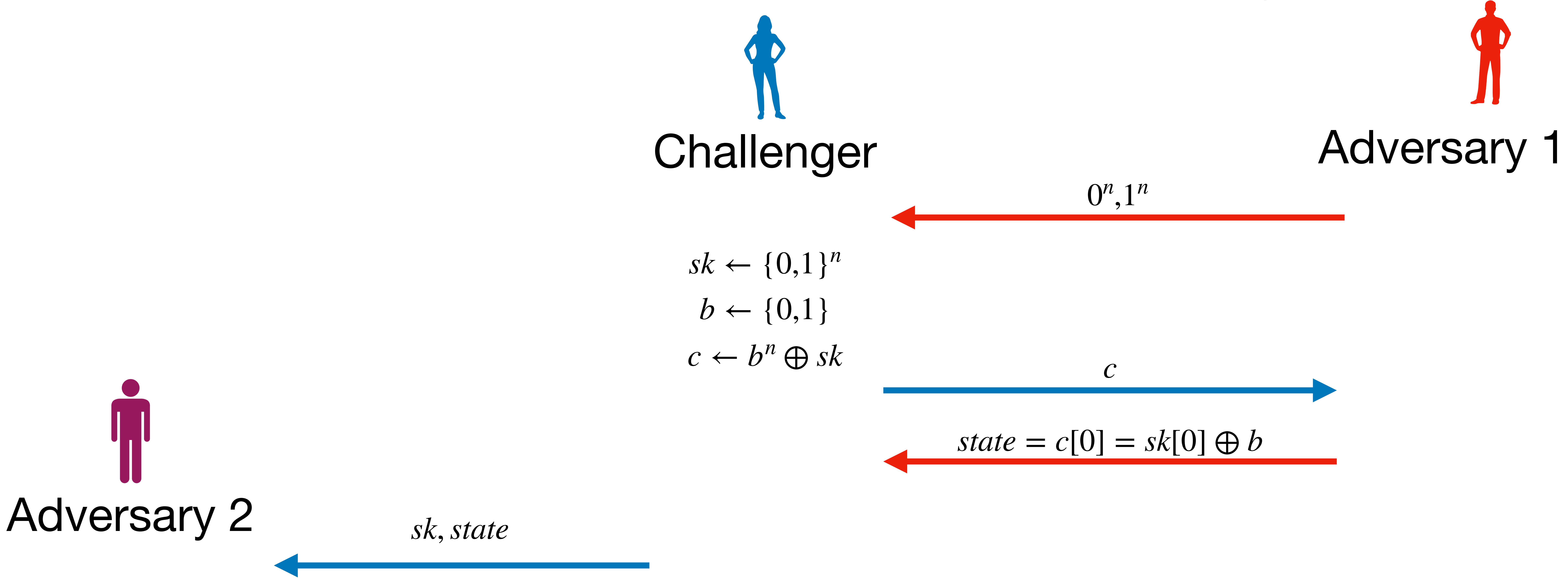
Adversary 2

Incompressible Security



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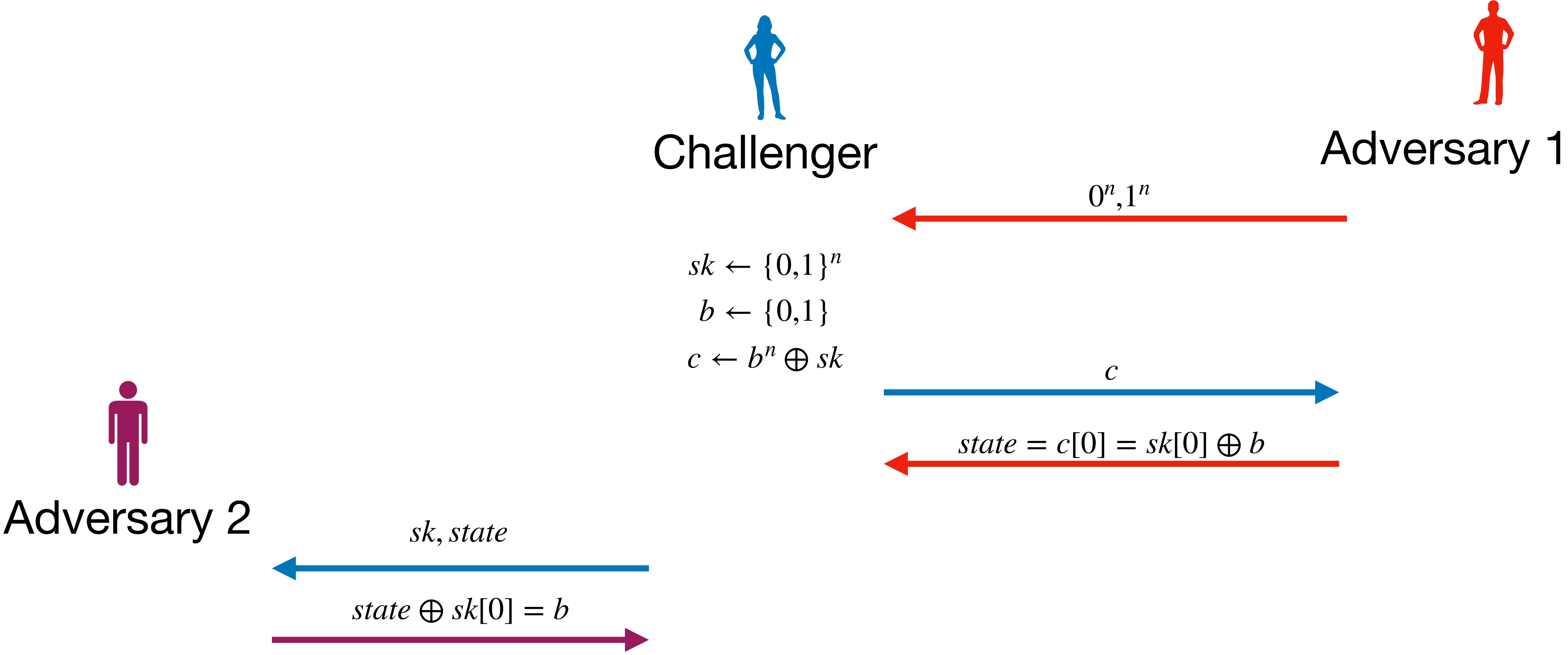
Adversary 2

$sk, state$

Incompressible Security



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$state = c[0] = sk[0] \oplus b$

Adversary 2

$sk, state$

$state \oplus sk[0] = b$

Fixing OTP (Dziembowski06)

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Incompressible Security

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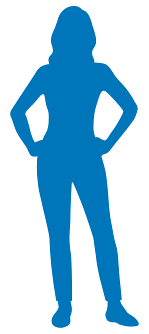

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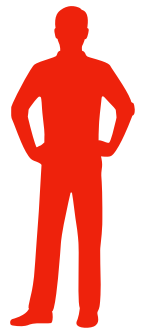
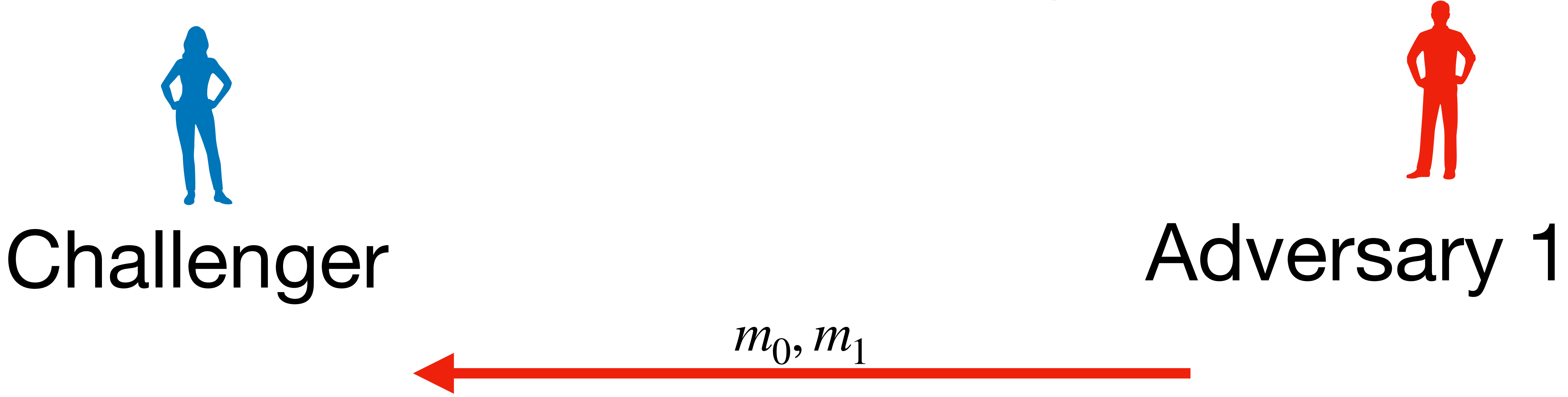


Adversary 1

Incompressible Security

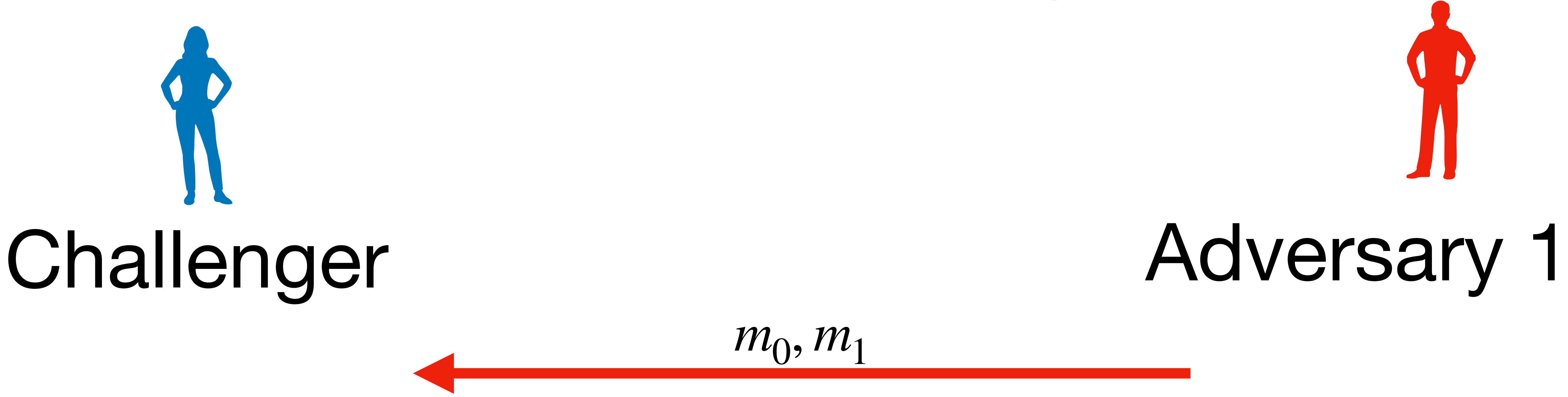


Challenger

Adversary 1

m_0, m_1

Incompressible Security



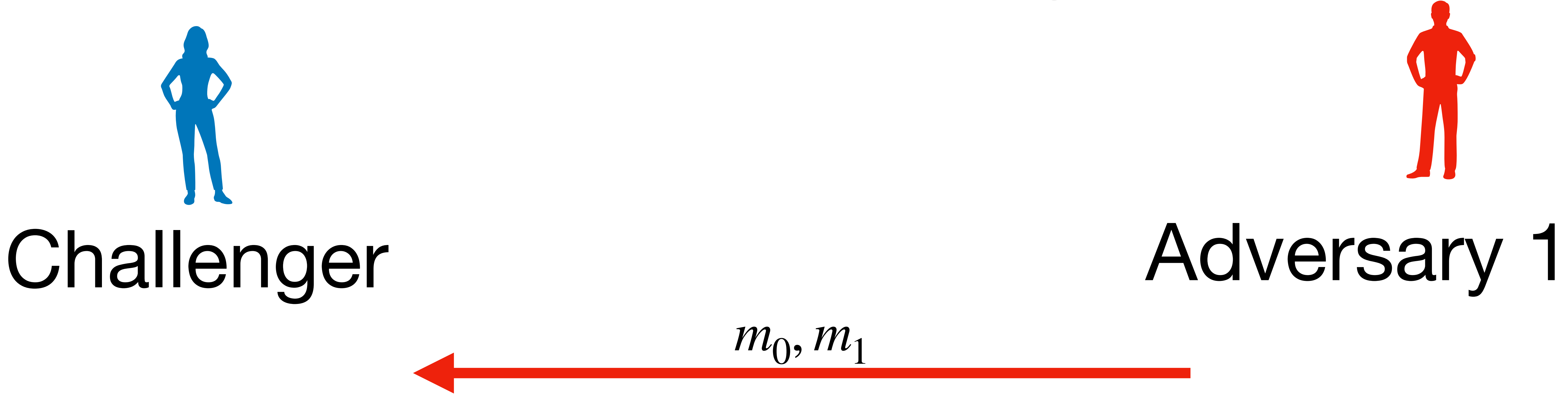
Challenger

Adversary 1

m_0, m_1

$sk \leftarrow \{0,1\}^\ell$

Incompressible Security



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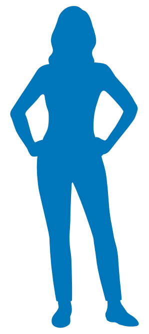

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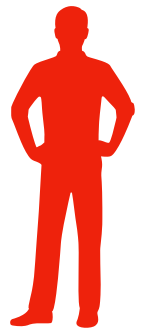


Adversary 1

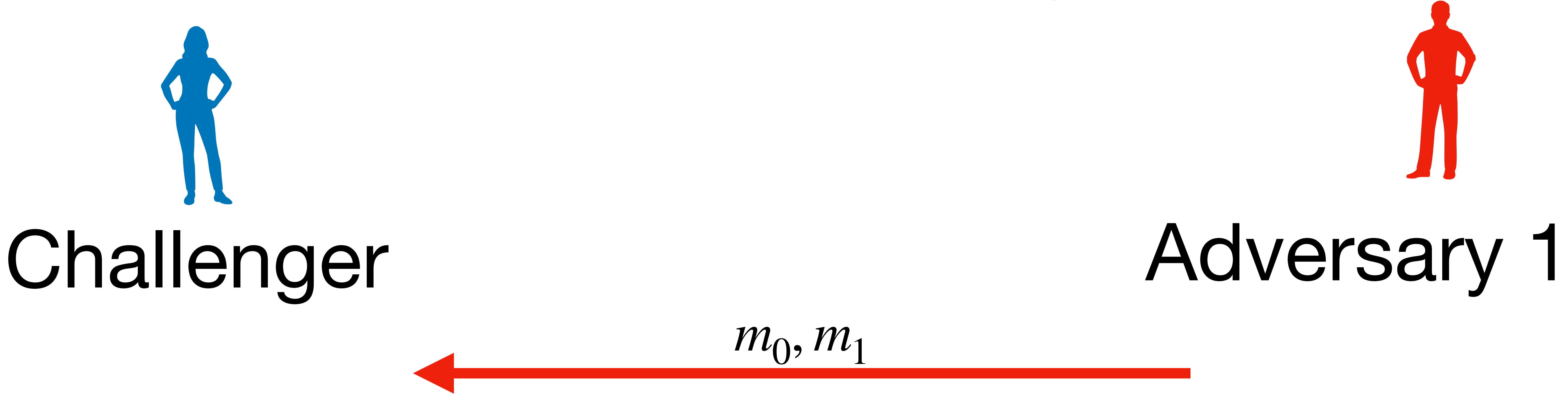
m_0, m_1

$$sk \leftarrow \{0,1\}^{\ell}$$

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

$$sk' = Ext(R; sk)$$

Incompressible Security



Challenger

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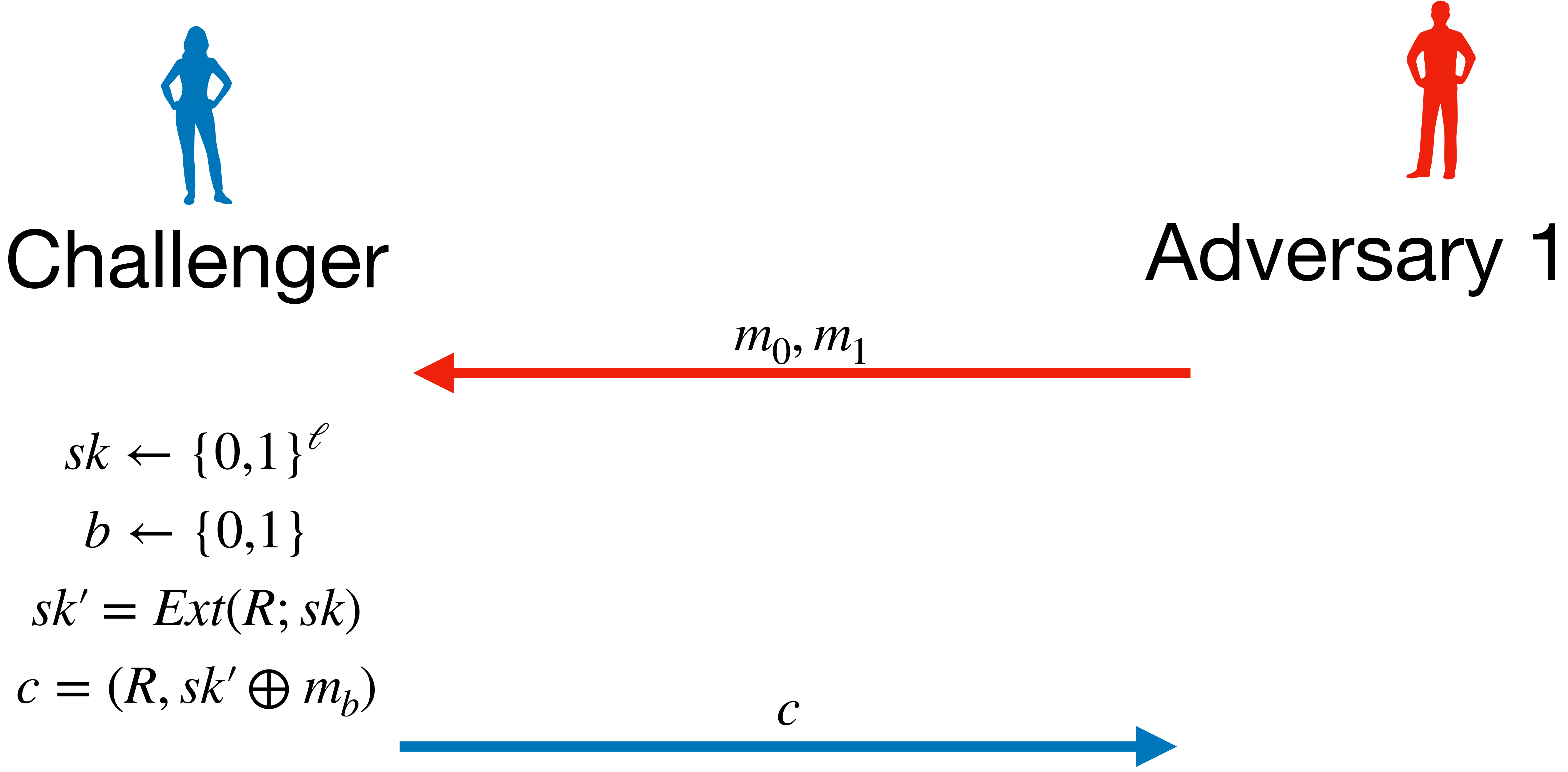

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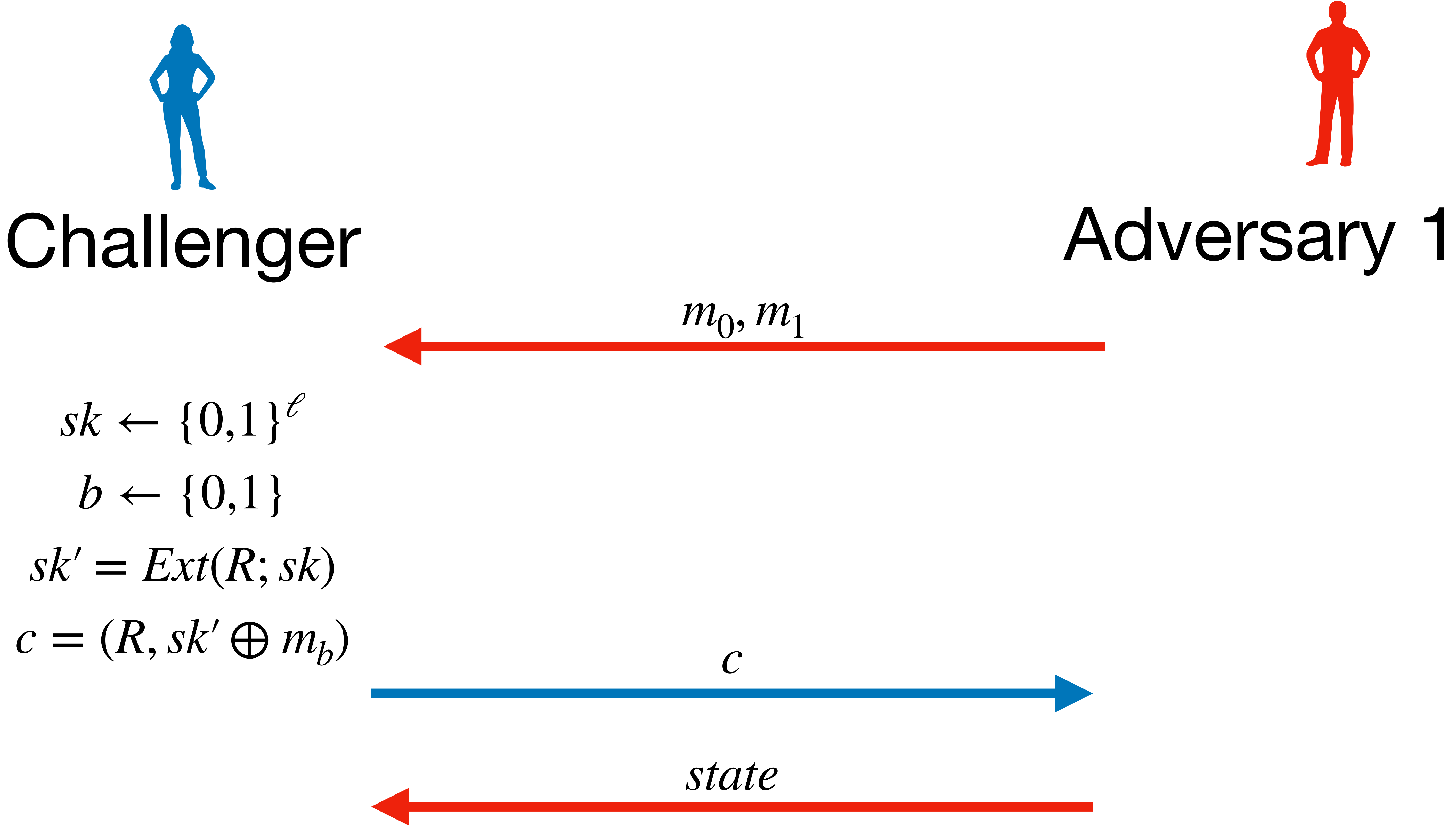

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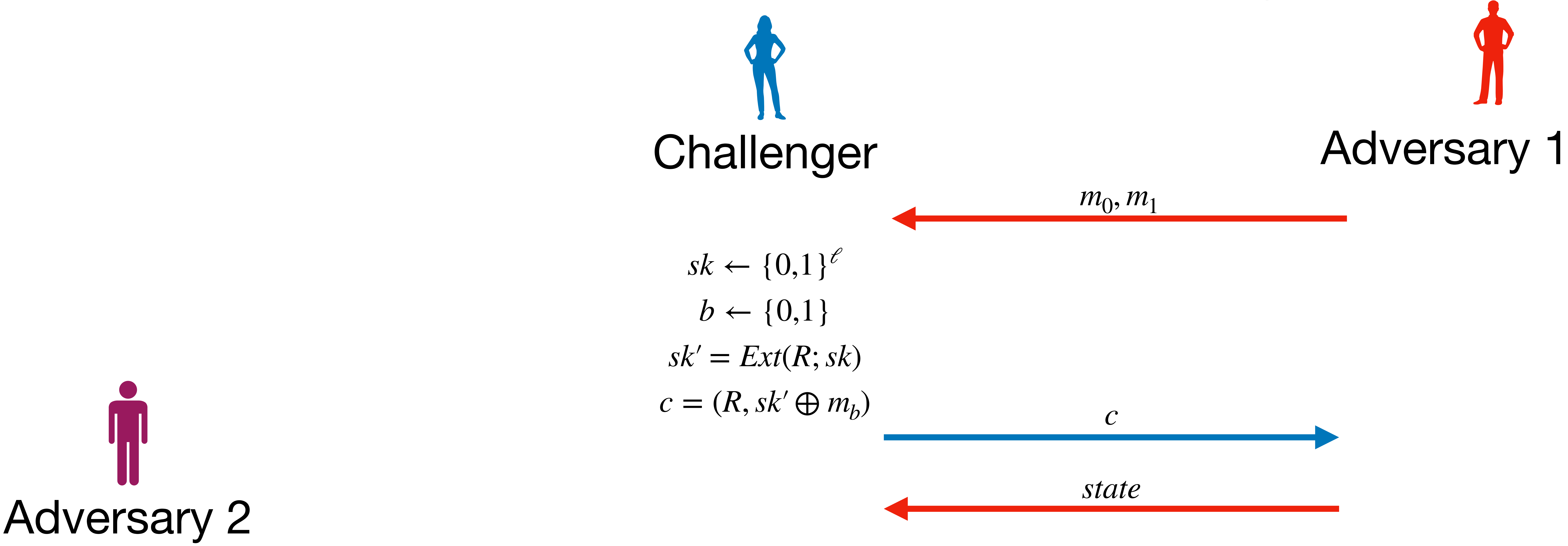
c

$state$

Incompressible Security



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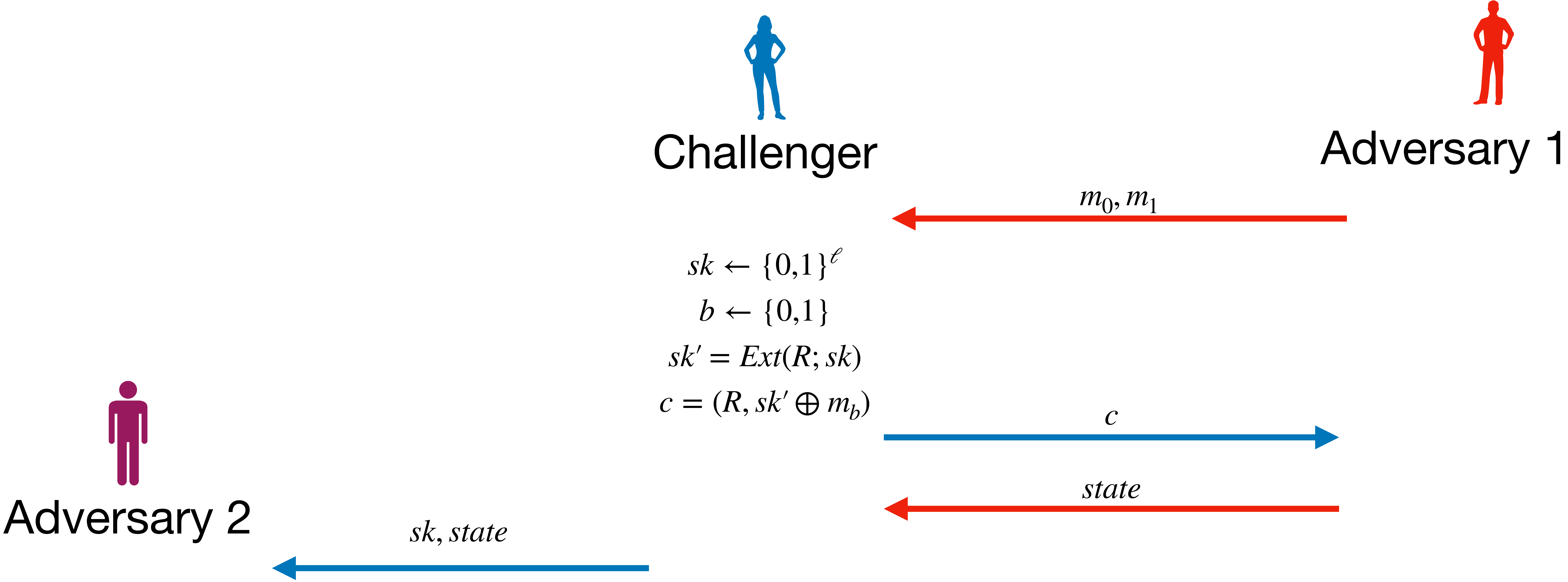
Adversary 2

Incompressible Security



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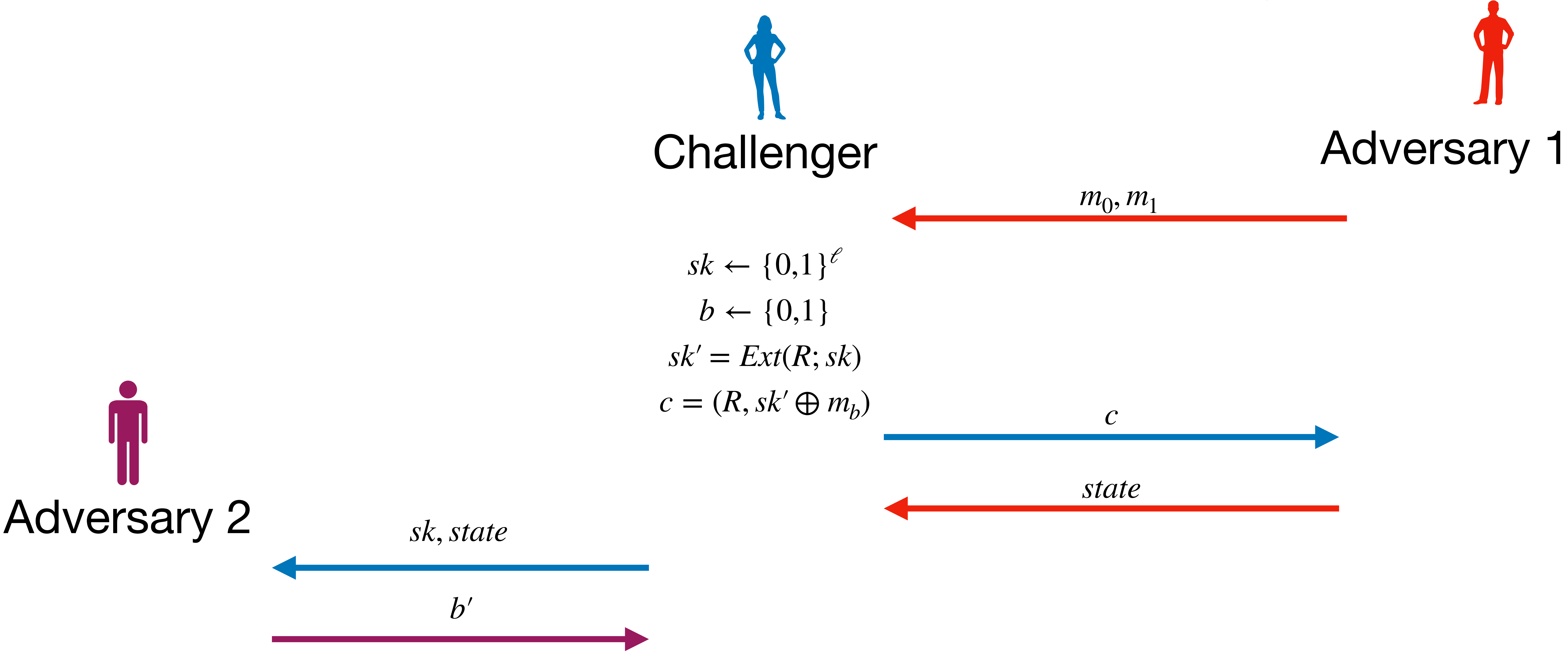
$state$

$sk, state$

Incompressible Security



Challenger

Adversary 1

Adversary 2

m_0, m_1

$sk \leftarrow \{0,1\}^\ell$

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

$sk' = Ext(R; sk)$

$c = (R, sk' \oplus m_b)$

c

$state$

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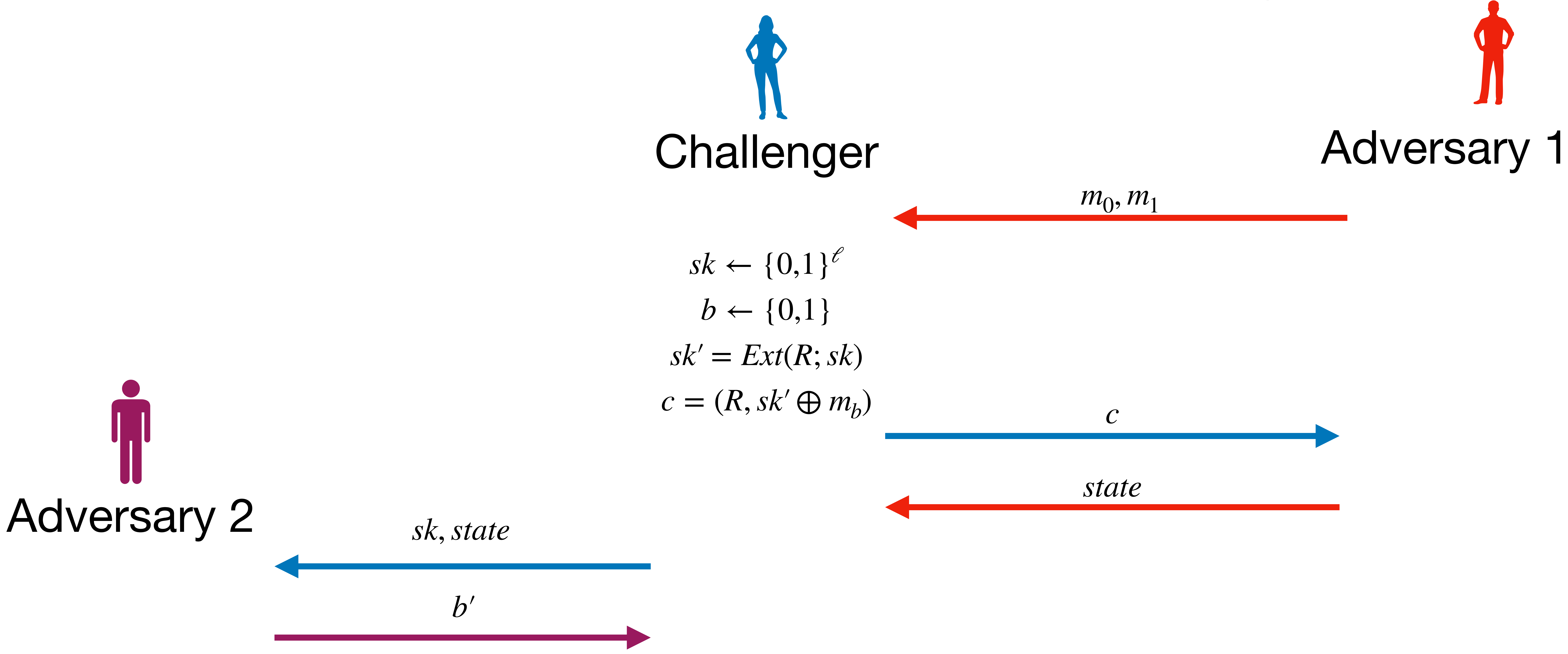
b'

Incompressible Security



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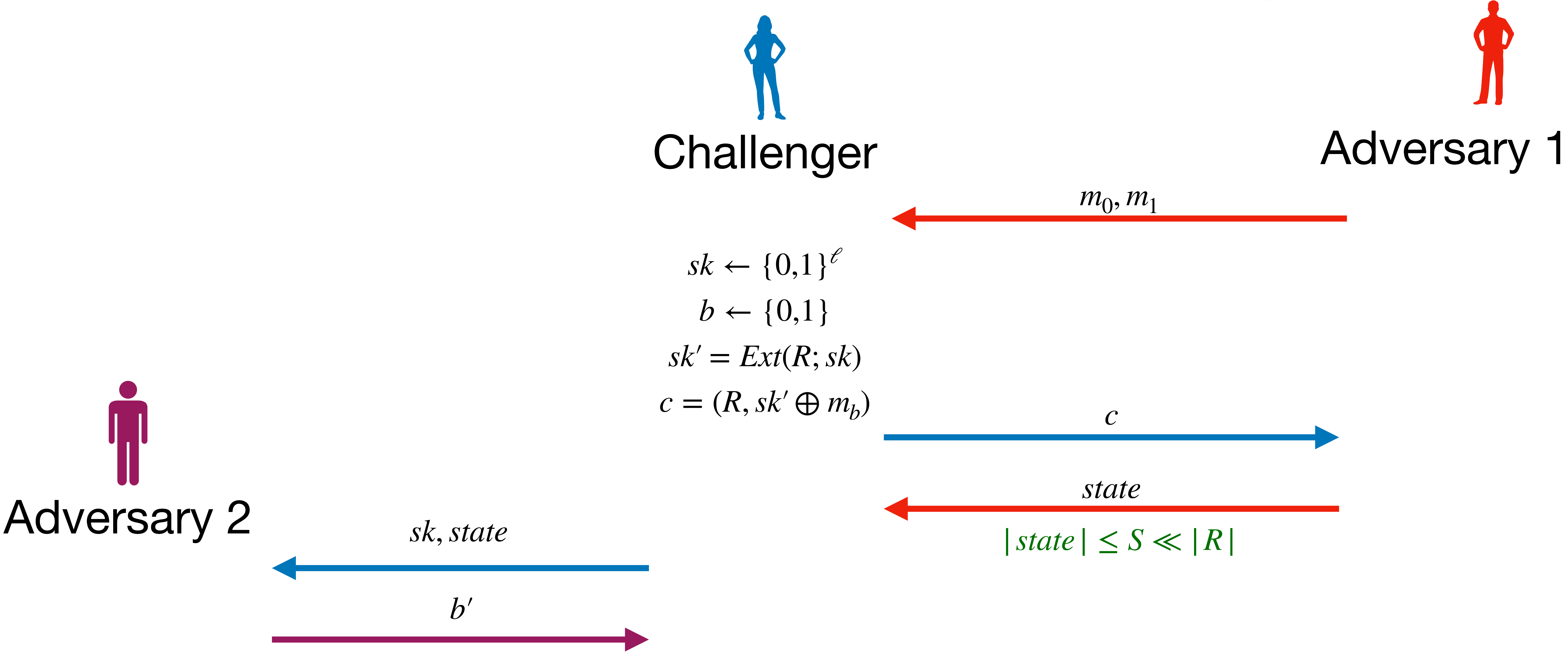

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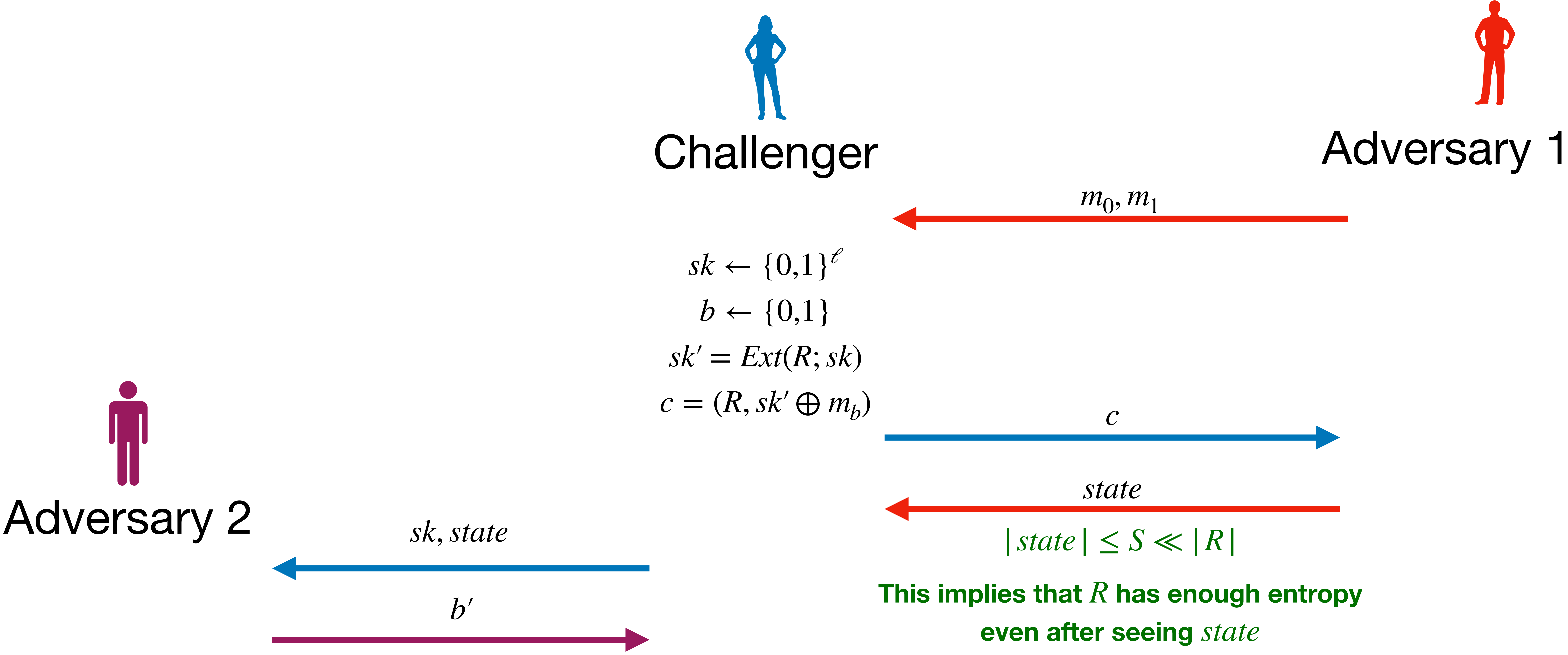

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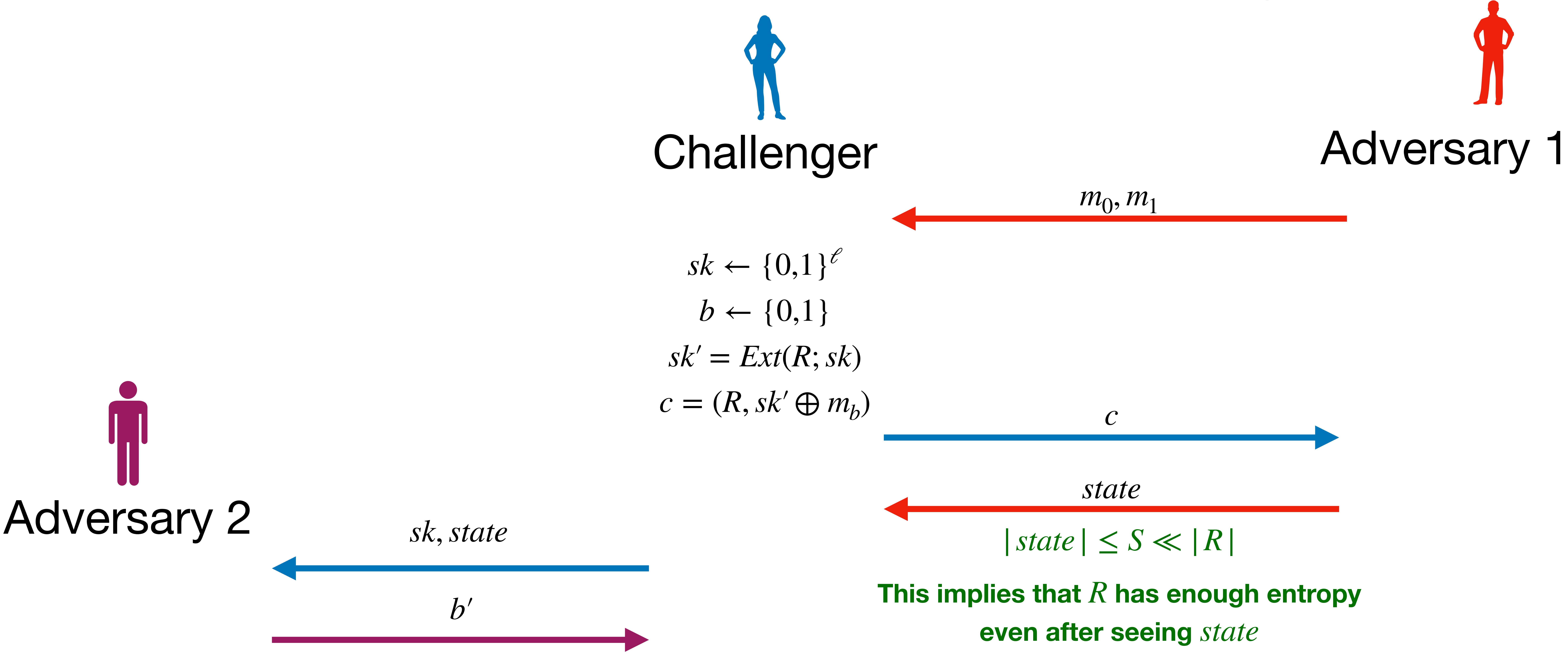

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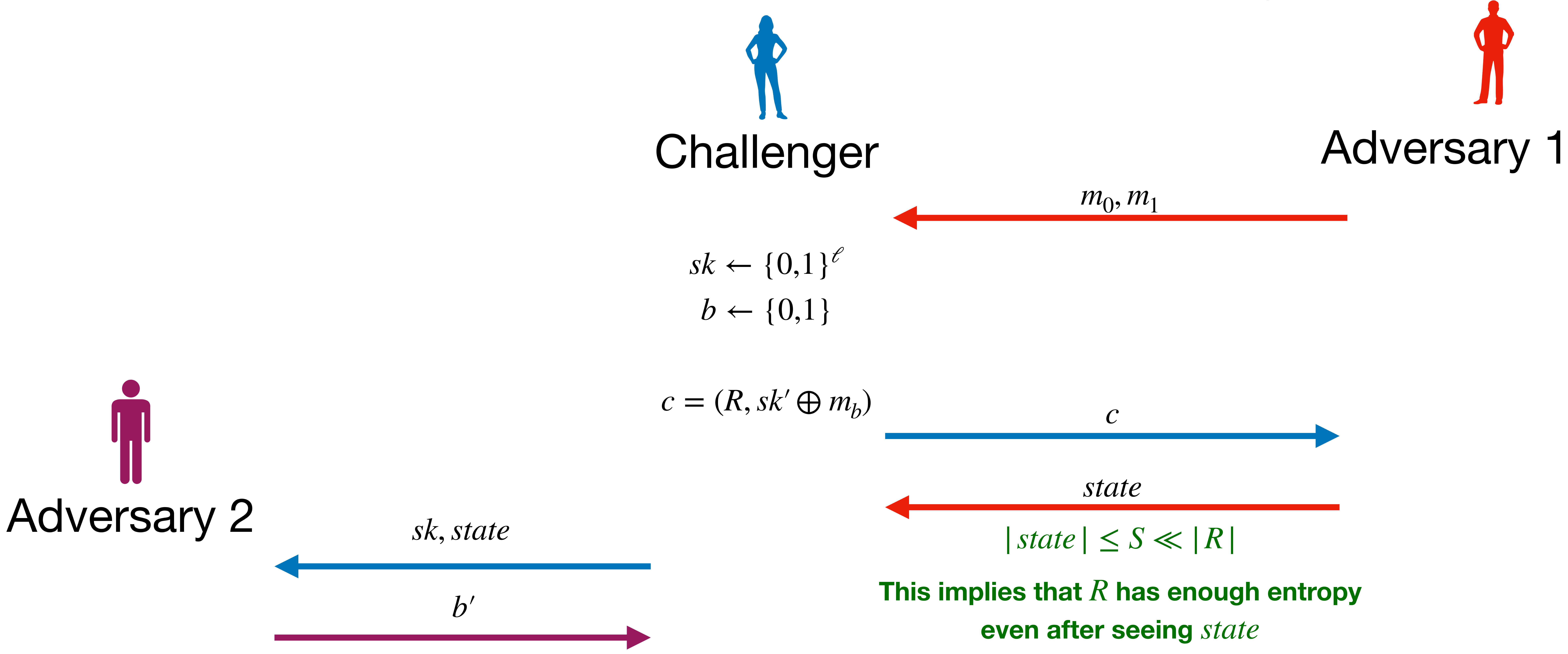

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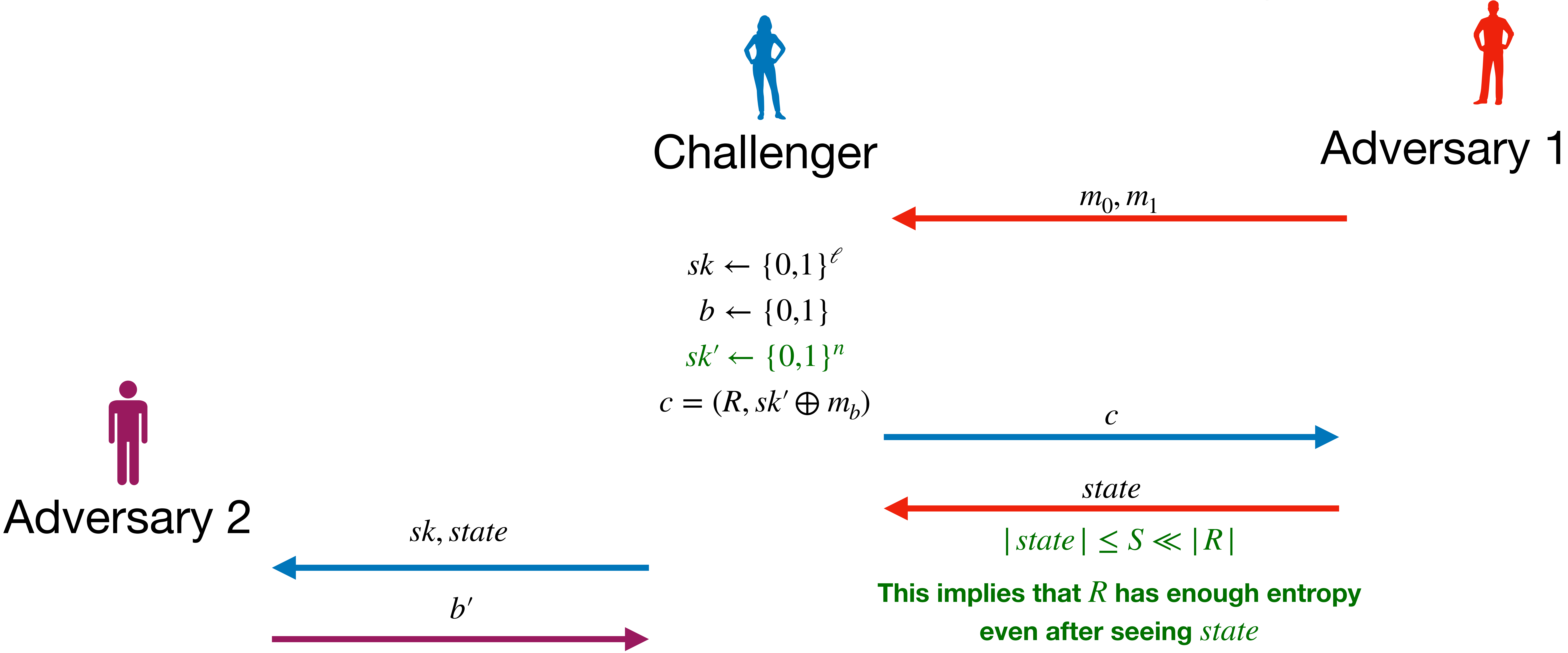

Challenger

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$sk' \leftarrow \{0,1\}^n$

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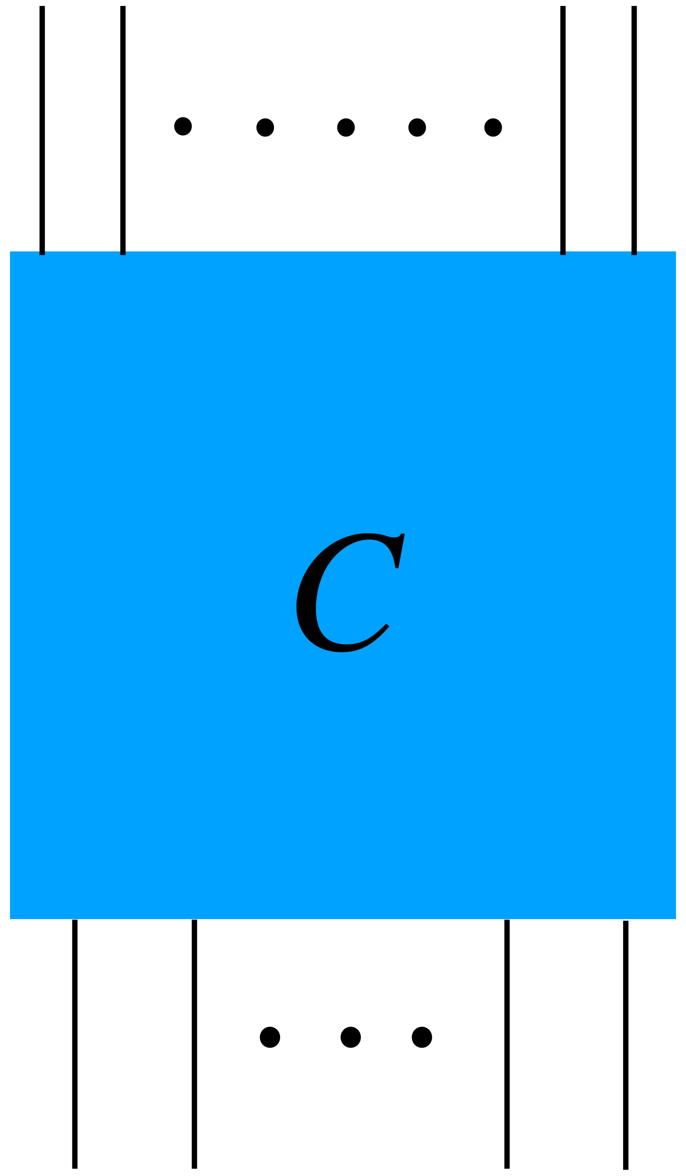
such that for any $(x_1, \ldots, x_n) \in \{0,1\}^n$

$$\tilde{C}(lab_{1,x_1}, lab_{2,x_2}, \ldots, lab_{n,x_n}) = C(x_1, \ldots, x_n)$$

Garbling Scheme

Garbling Scheme



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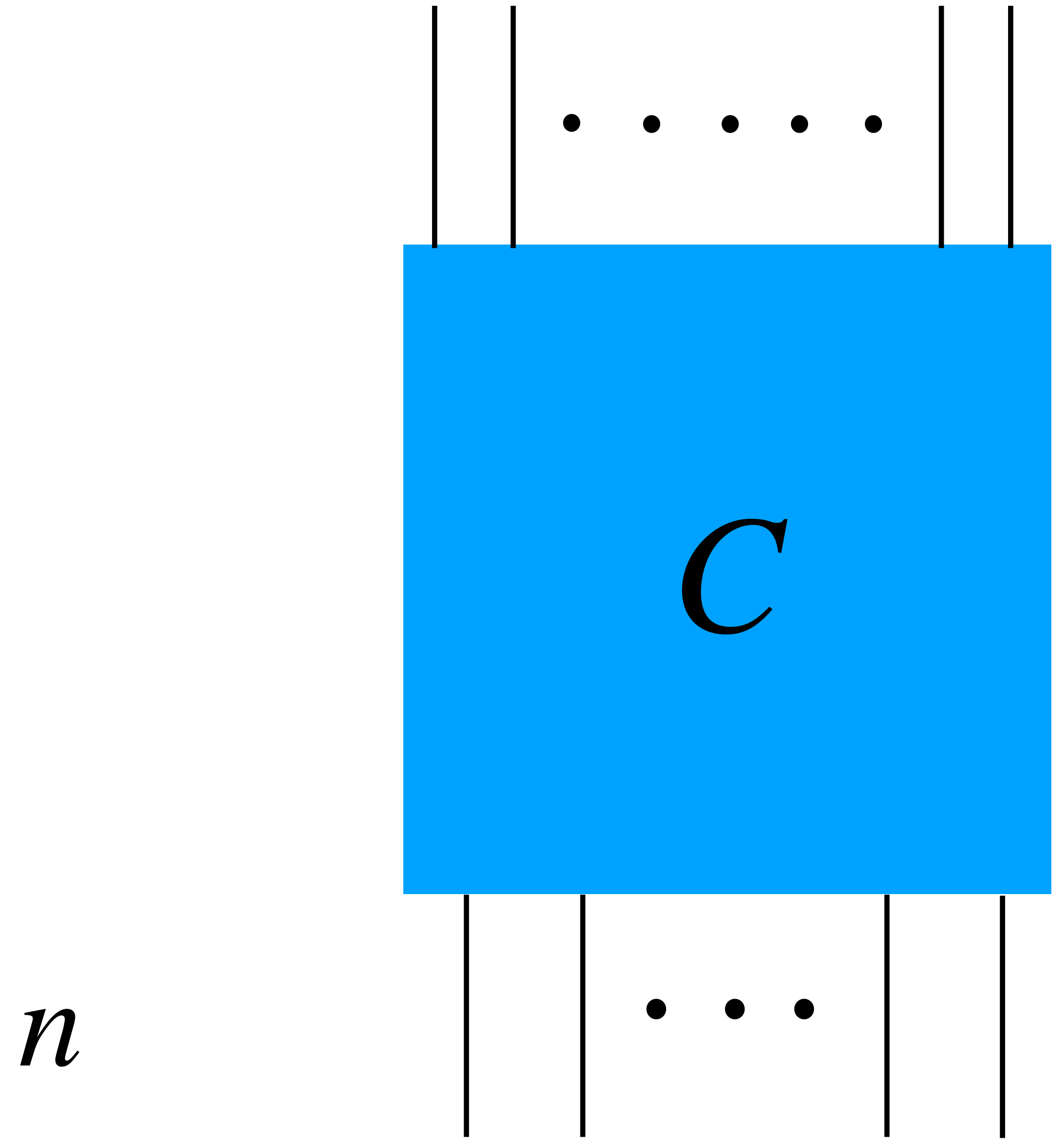

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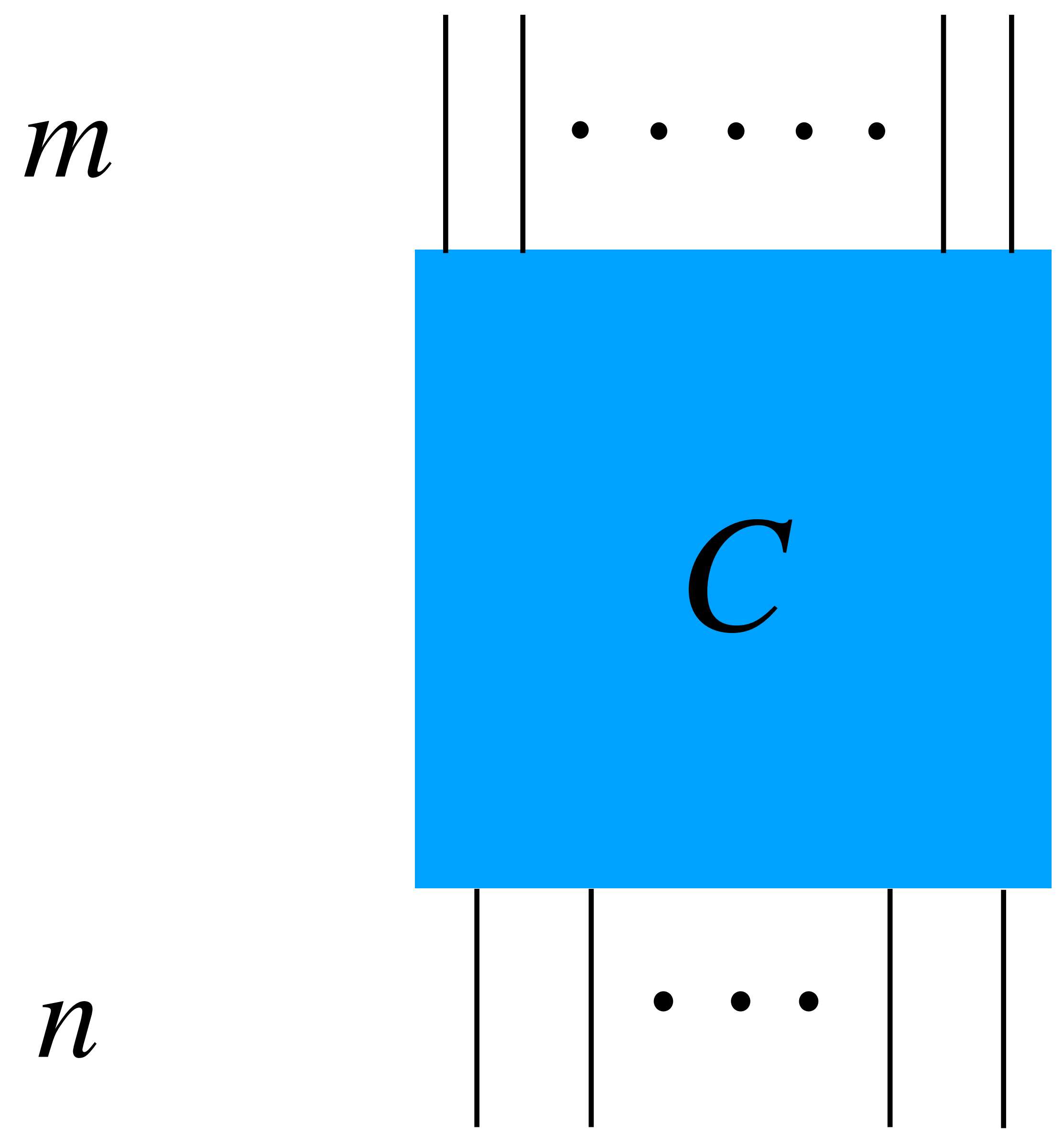

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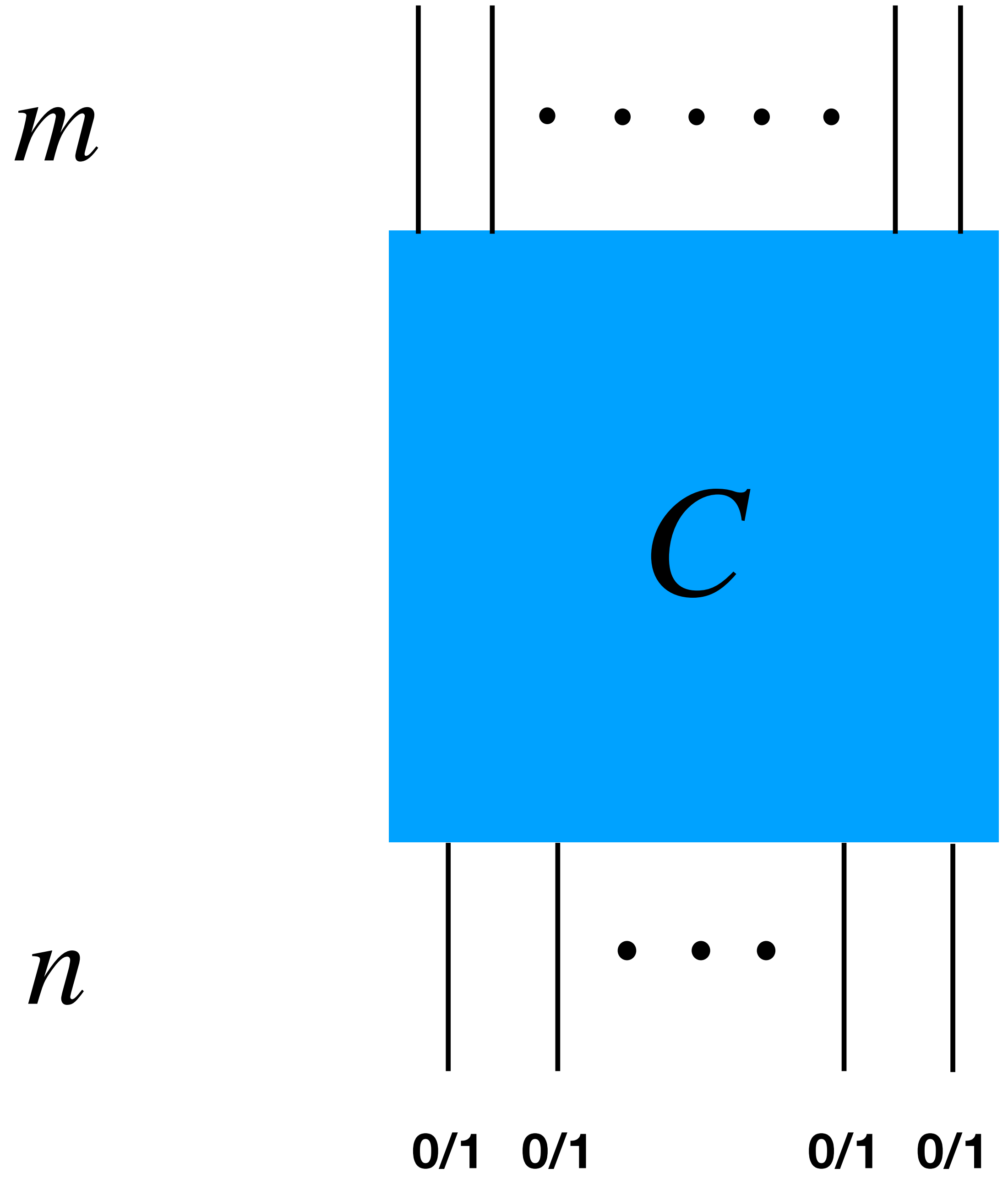

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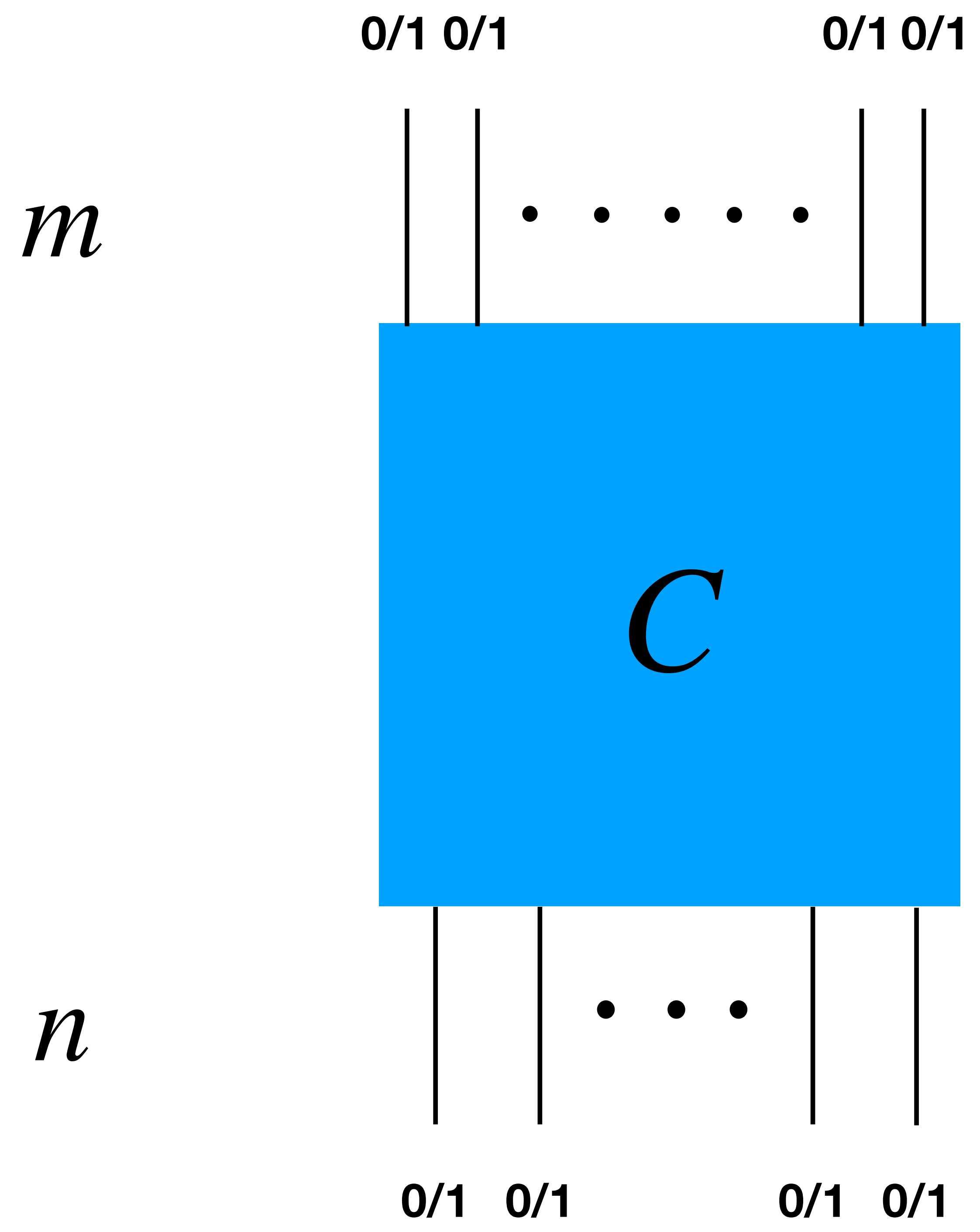

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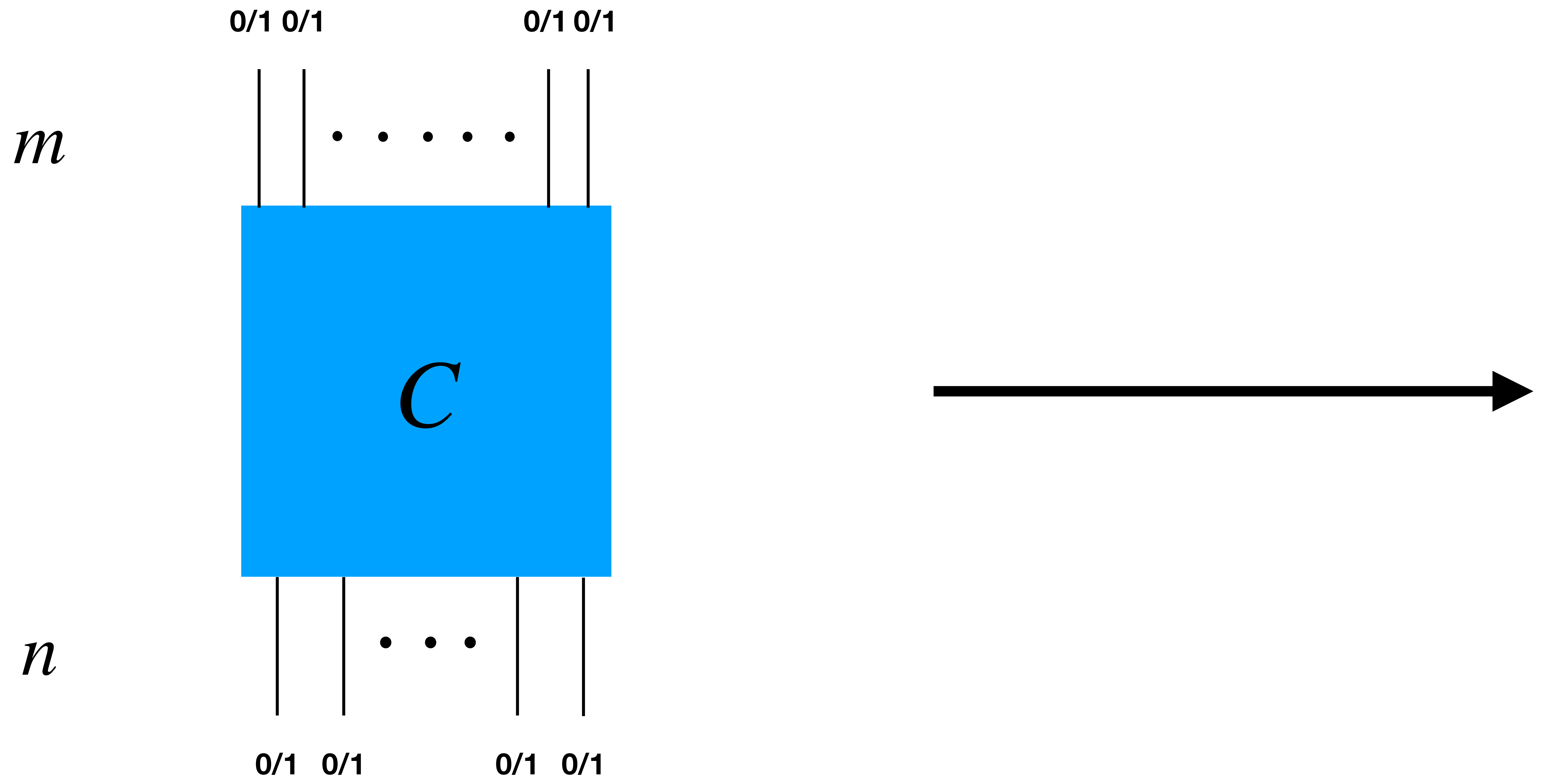

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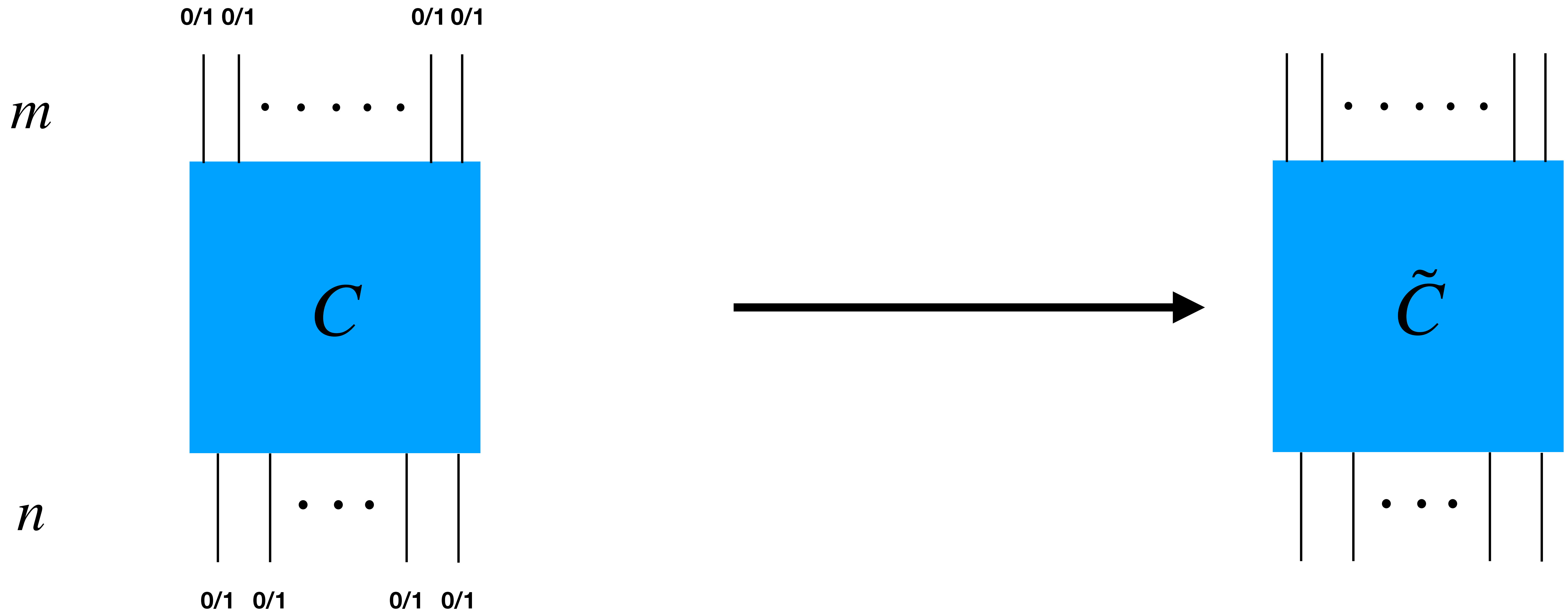

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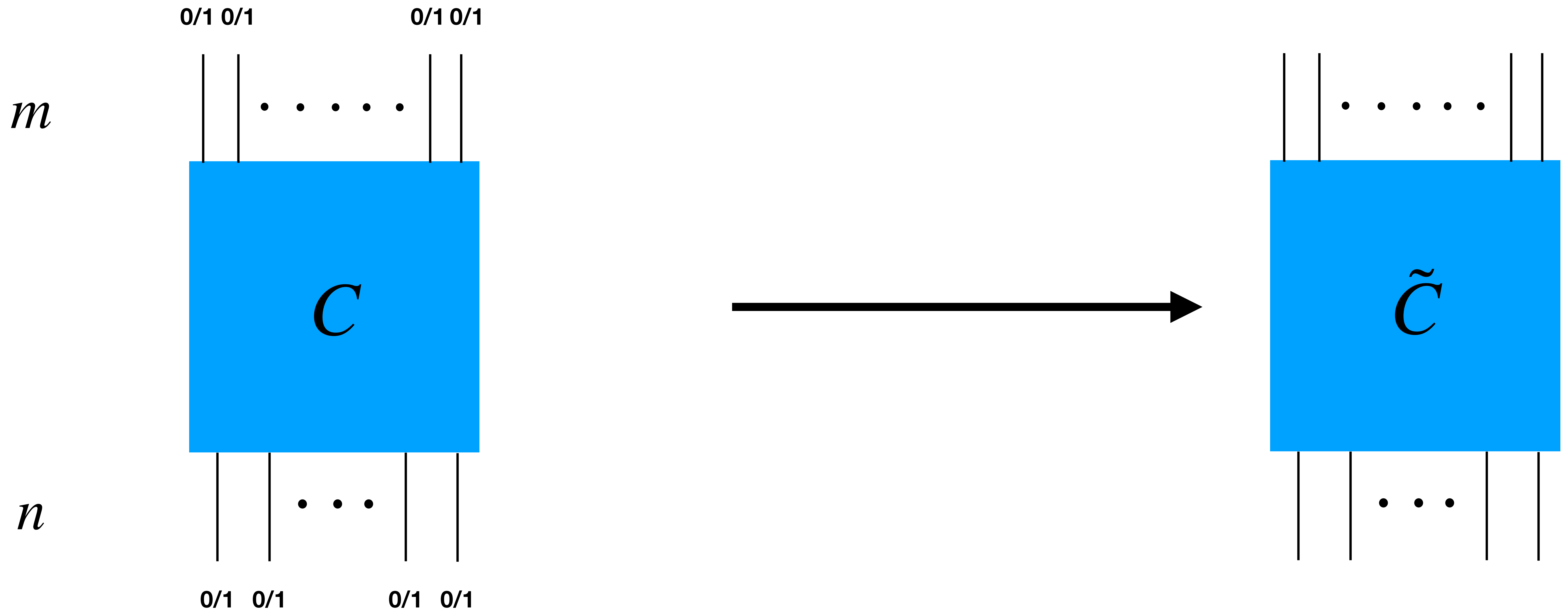

$\{lab_{1,0}, lab_{2,0}, \ldots, lab_{n,0}\}$

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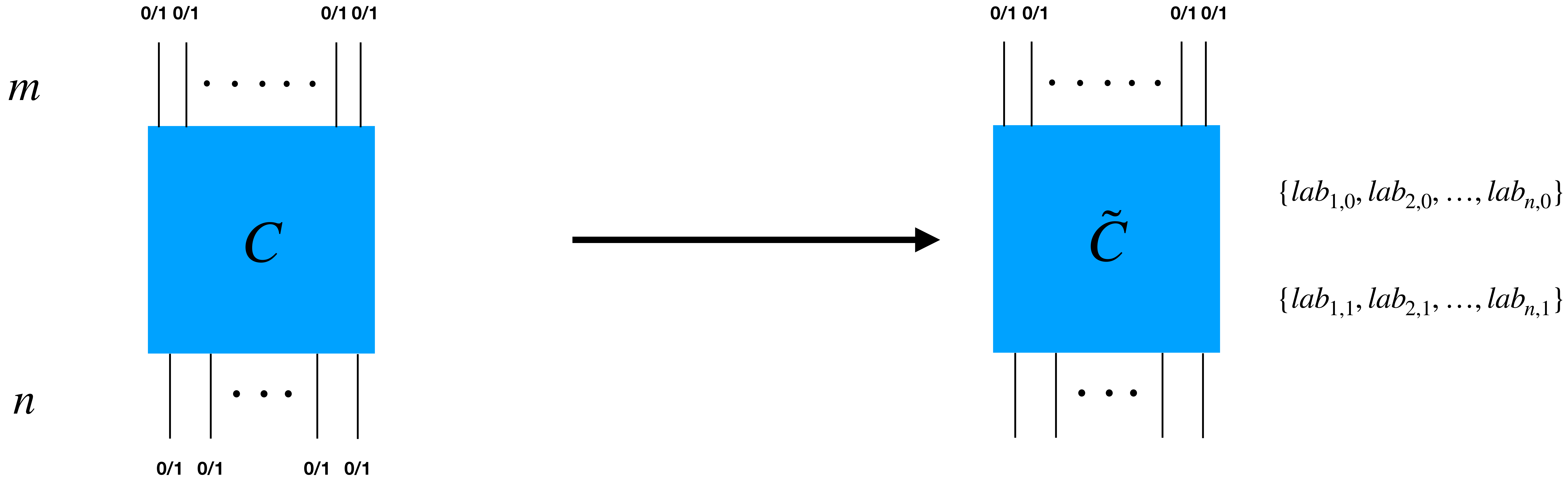
Garbling Scheme



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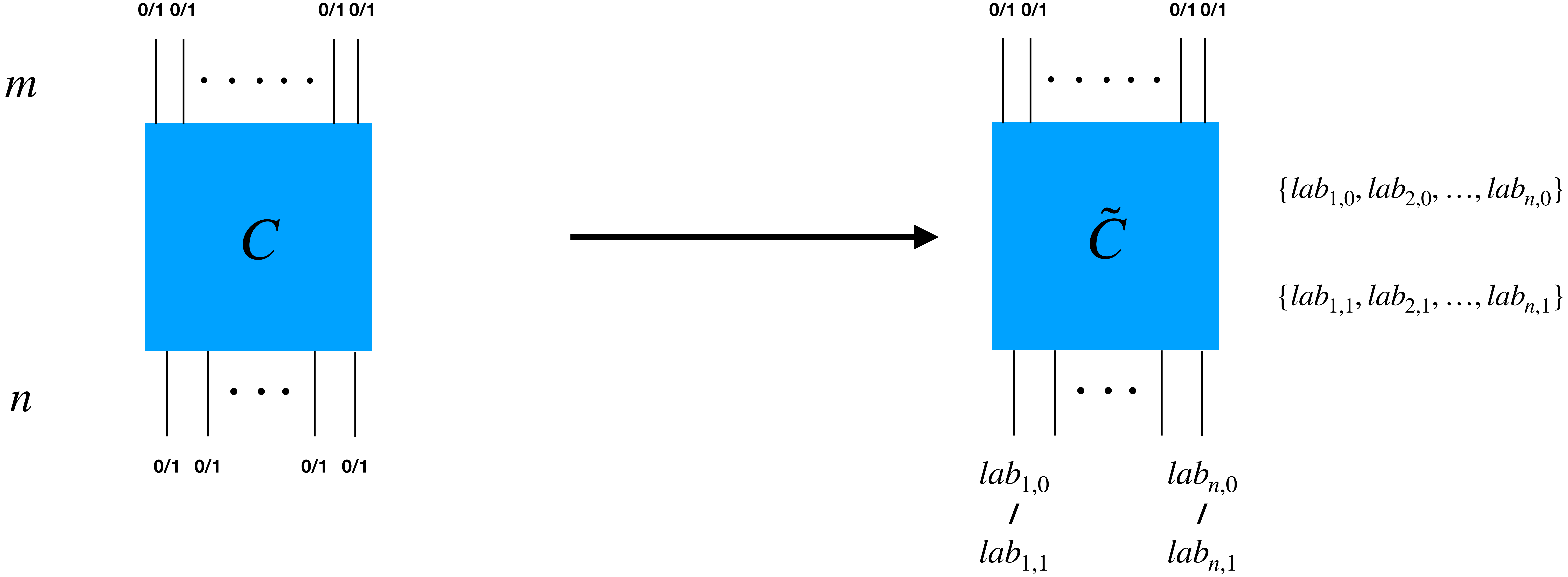

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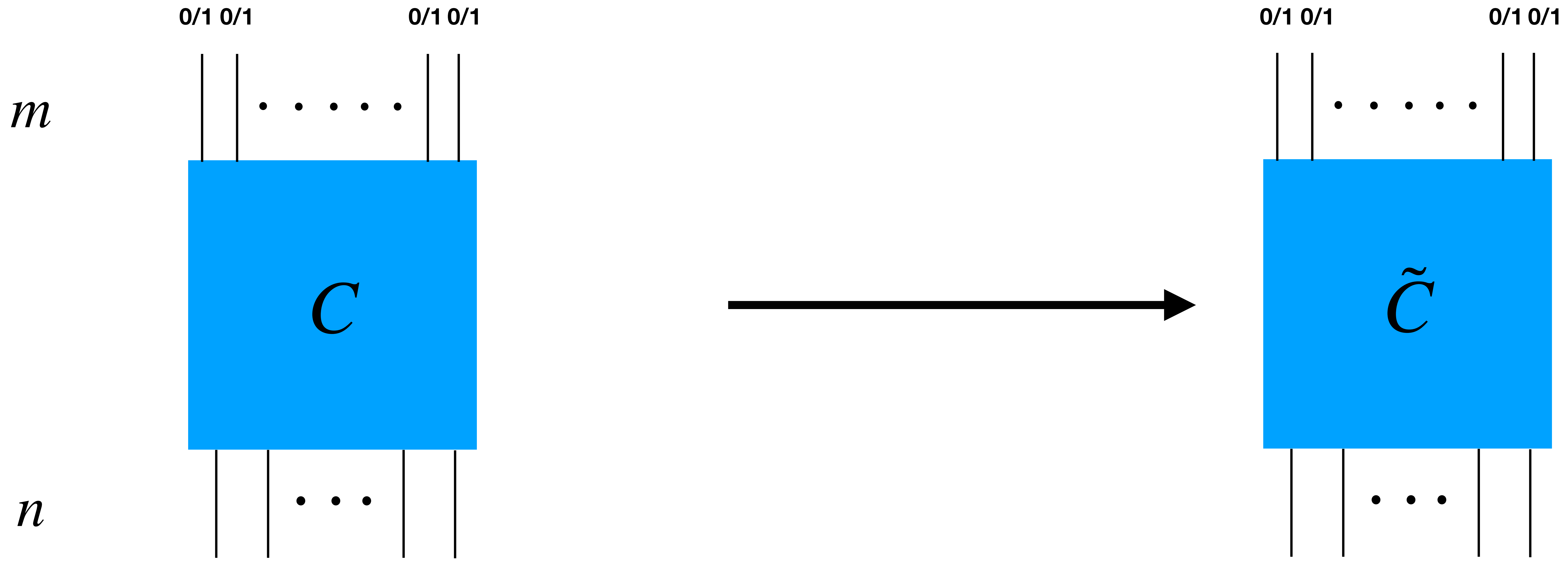

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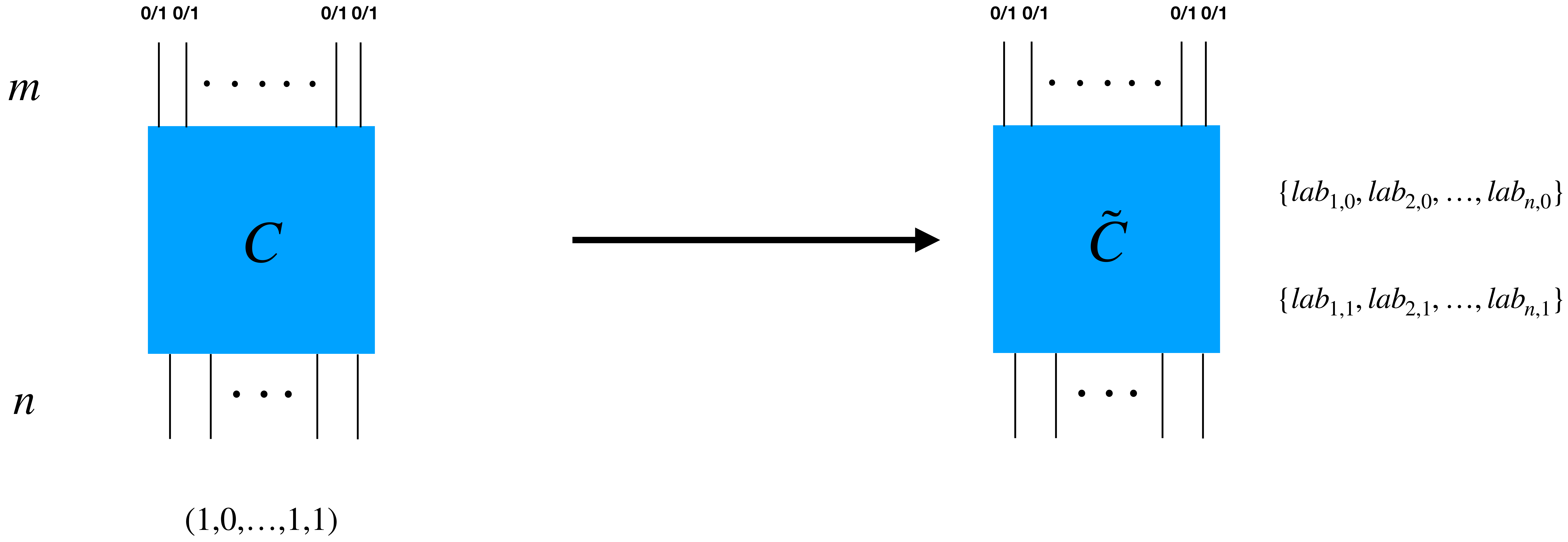

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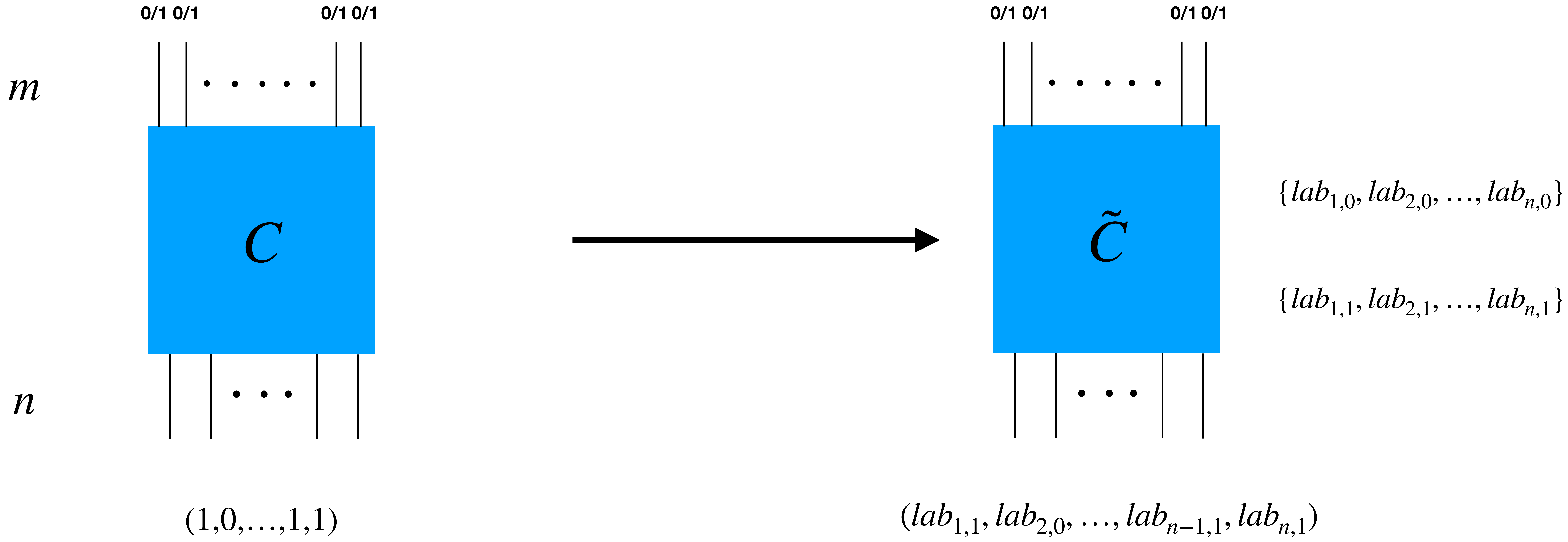

0/1 0/1 0/1 0/1

m

C

n

$(1,0,\ldots,1,1)$

0/1 0/1 0/1 0/1

$\tilde{C}$

$\{lab_{1,0}, lab_{2,0}, \ldots, lab_{n,0}\}$

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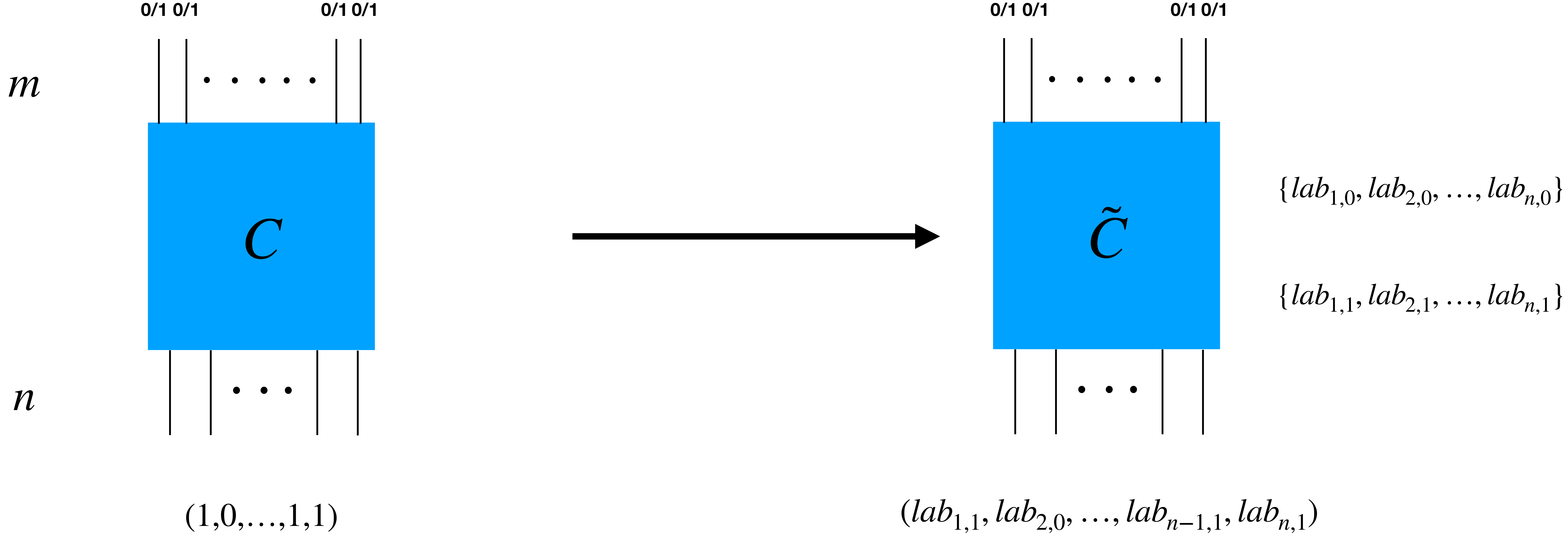
$(lab_{1,1}, lab_{2,0}, \ldots, lab_{n-1,1}, lab_{n,1})$

Garbling Scheme



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$(lab_{1,1}, lab_{2,0}, \ldots, lab_{n-1,1}, lab_{n,1})$

Correctness - For any x, $C(x) = \tilde{C}(\{lab_{i,x_i}\})$.

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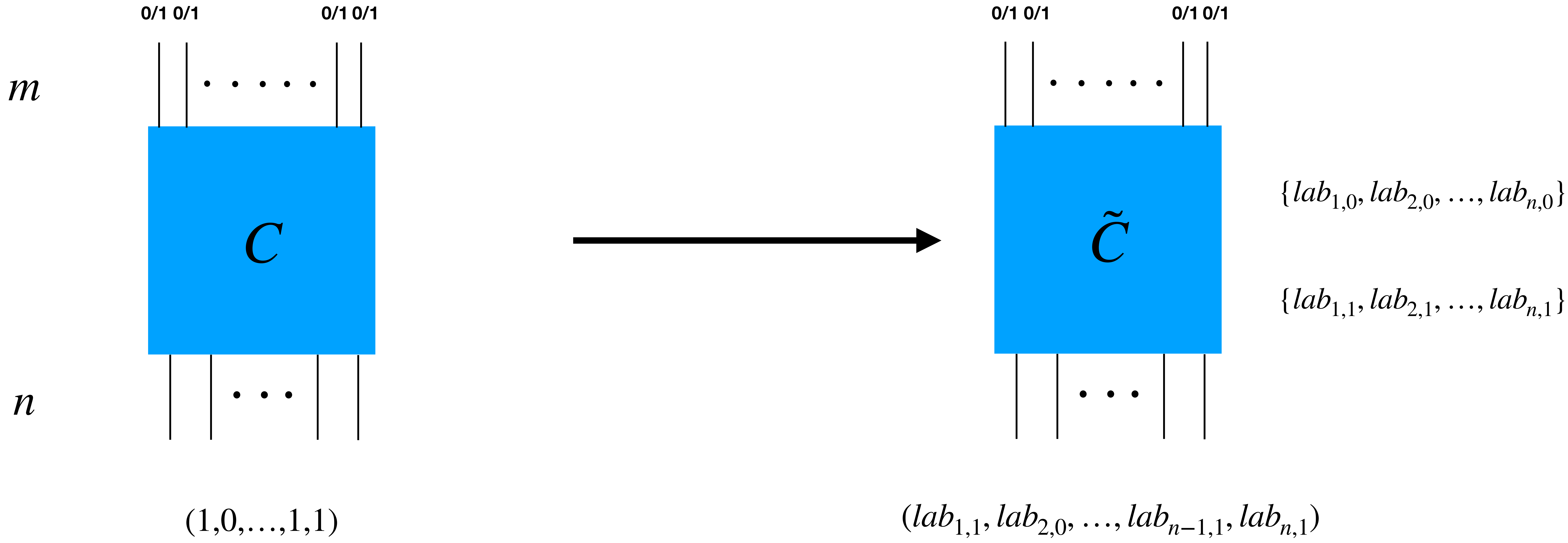

Correctness - For any x, $C(x) = \tilde{C}(\{lab_{i,x_i}\})$.

Security - Given $|C|$, $C(x)$, the simulator can generate $\tilde{C}$ and $\{lab_{i,x_i}\}$

Our Construction of Incomp PKE

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- $Setup()$:

  Generate $2n$ public/secret key,

  $$(pk_{i,b}, sk_{i,b}) \leftarrow PKE.Setup()$$

  Generate $k \leftarrow incSKE.Setup()$.

  $pk = \{pk_{i,b}\}$ and $sk = (k, \{sk_{i,k_i}\})$

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- $Enc(pk, m)$:

  $(\tilde{C}, lab_{i,b}) \leftarrow Garble(incSKE.Enc(\cdot, m))$

  $c_{i,b} \leftarrow PKE.Enc(pk_{i,b}, lab_{i,b})$

  Return $(\tilde{C}, \{c_{i,b}\})$

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- $Enc(pk, m)$:
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  Return m

Incompressible IBE & FE

Identity Based Encryption

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- $Dec(sk_{id}, c)$: Outputs a message or error.

Incompressible (IBE) Security

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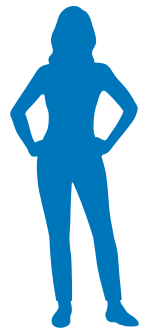
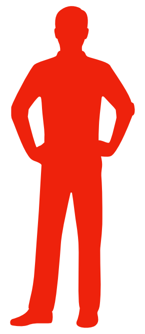
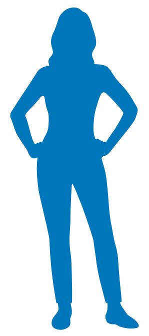


Challenger



Adversary 1

Incompressible (IBE) Security



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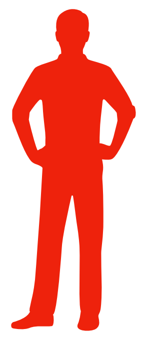
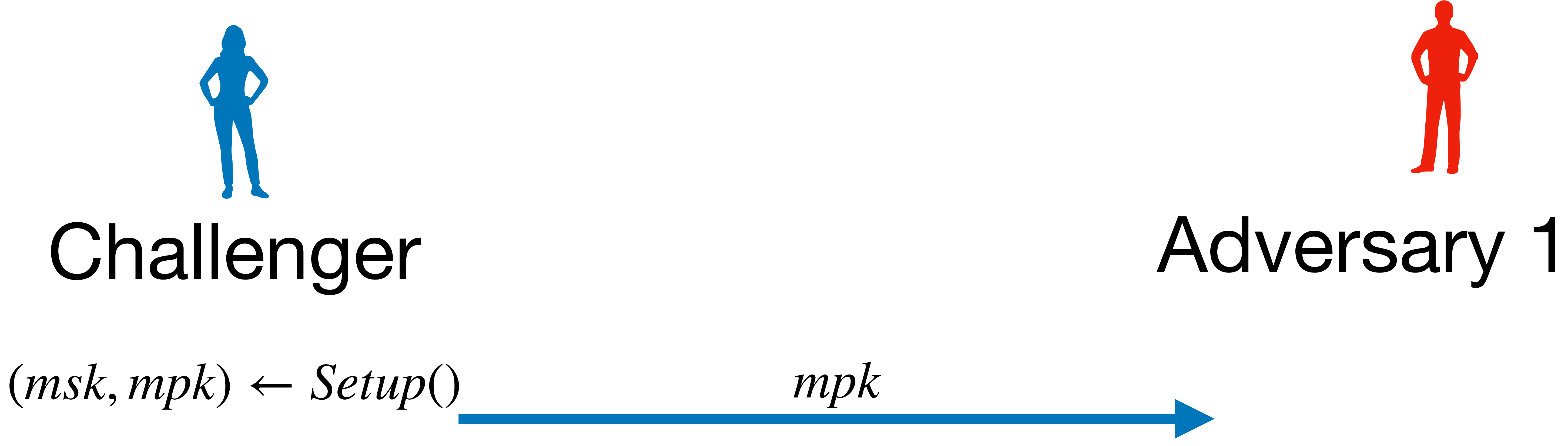


Adversary 1

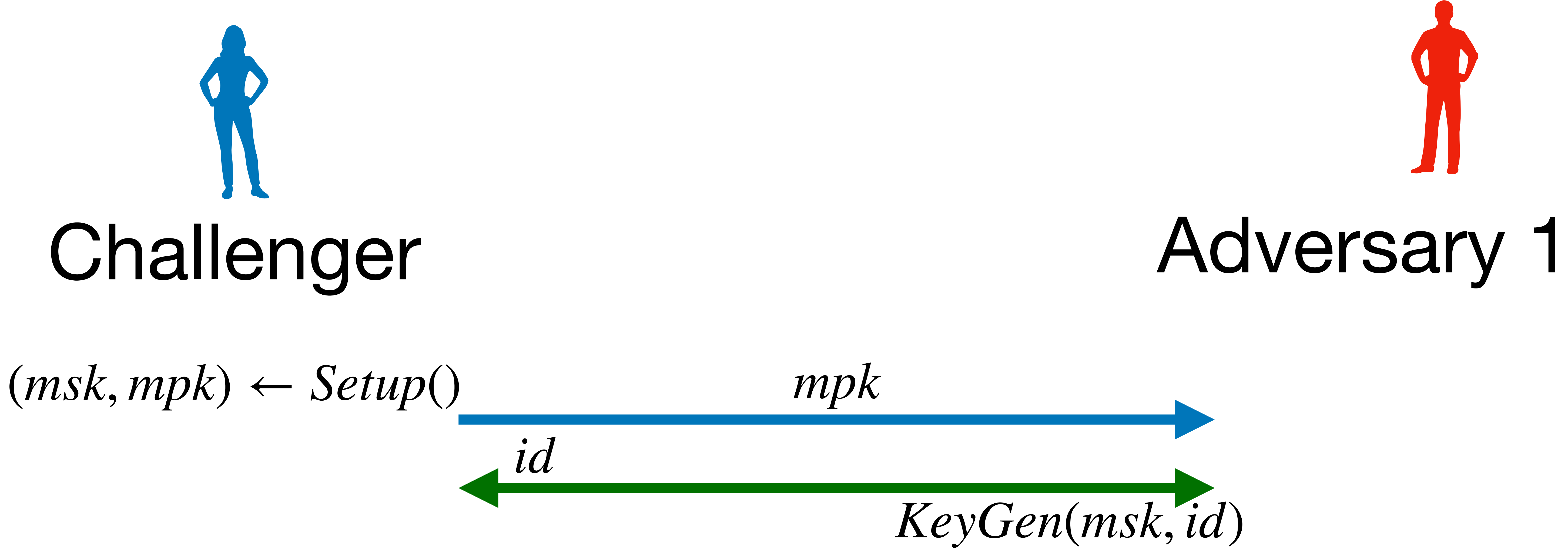
$$(msk, mpk) \leftarrow Setup()$$

Incompressible (IBE) Security



$(msk, mpk) \leftarrow Setup()$ $\xrightarrow{mpk}$

Incompressible (IBE) Security



Challenger

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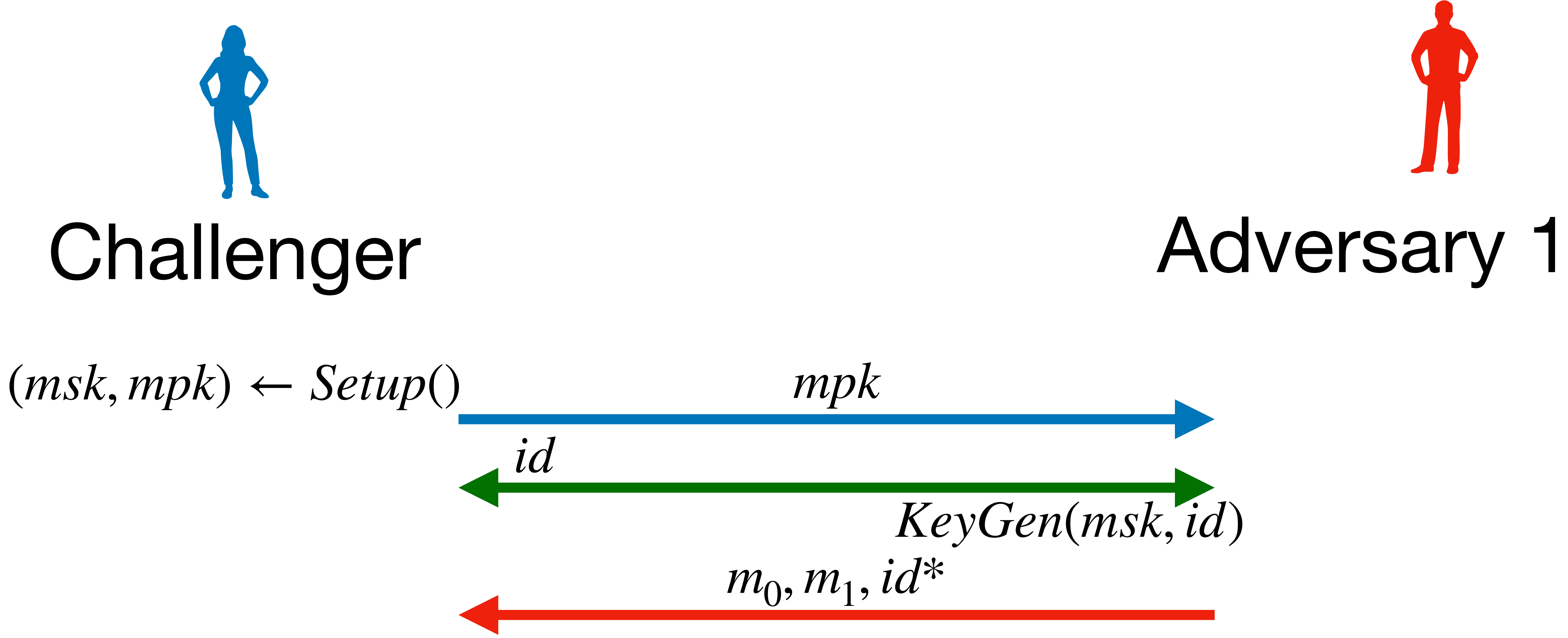
mpk

id

$KeyGen(msk, id)$

Incompressible (IBE) Security



Challenger

Adversary 1

$(msk, mpk) \leftarrow Setup()$

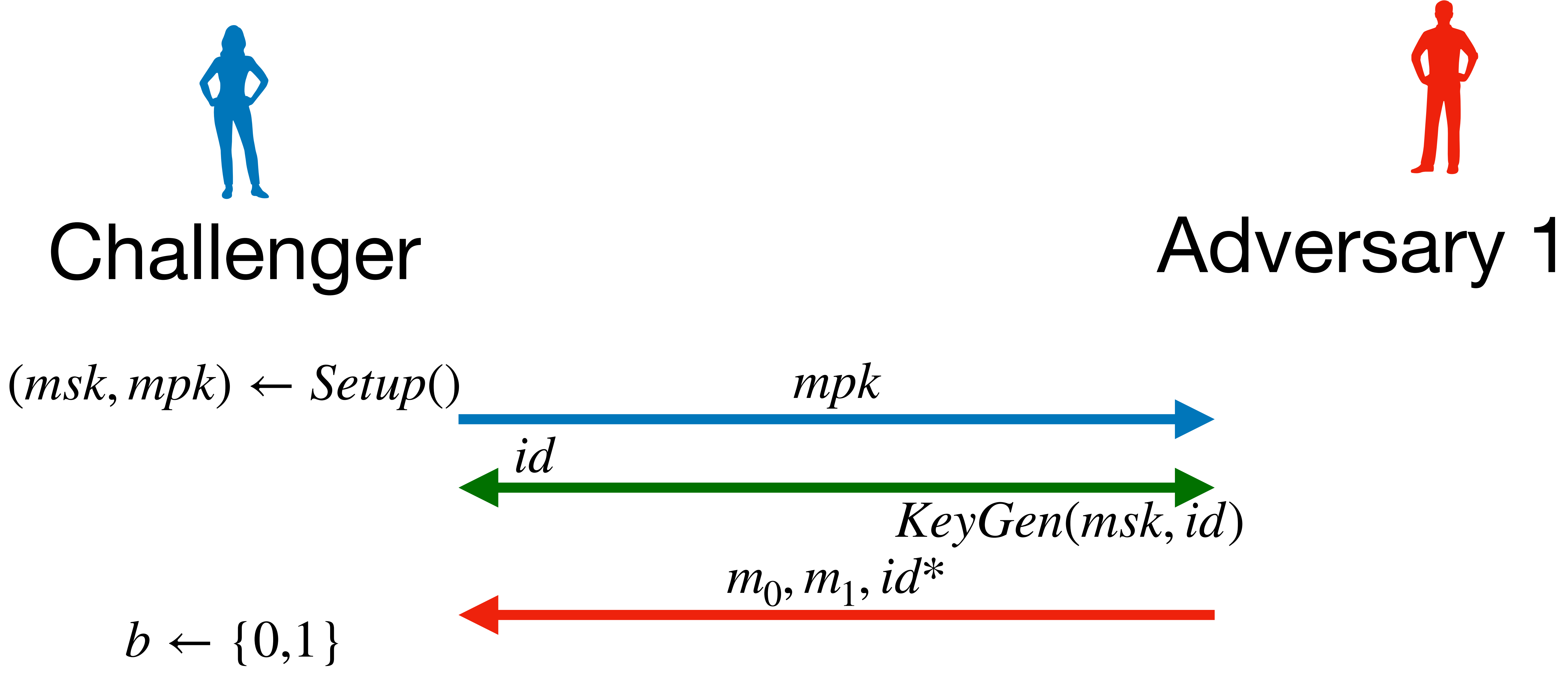
mpk

id

$KeyGen(msk, id)$

m_0, m_1, id^*

Incompressible (IBE) Security



Challenger

Adversary 1

$(msk, mpk) \leftarrow Setup()$

mpk

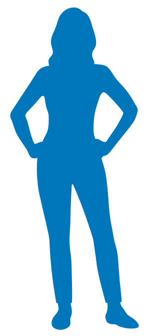
id

$KeyGen(msk, id)$

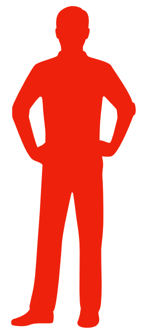
m_0, m_1, id^*

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

Incompressible (IBE) Security



Challenger



Adversary 1

$(msk, mpk) \leftarrow Setup()$ $\xrightarrow{mpk}$

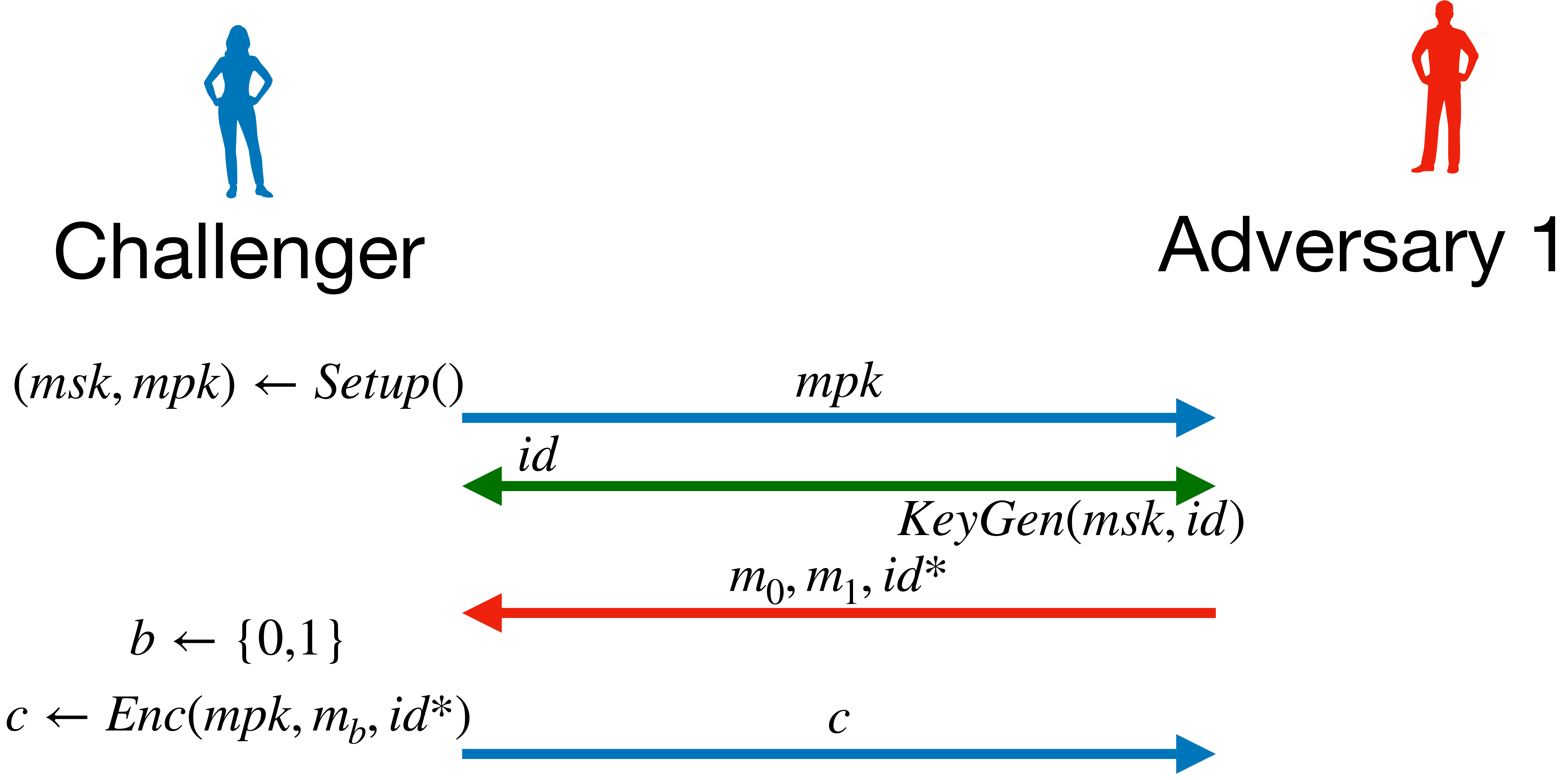
$\xleftarrow{id}$ $\xrightarrow{KeyGen(msk, id)}$

$\xleftarrow{m_0, m_1, id^*}$

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

$c \leftarrow Enc(mpk, m_b, id^*)$

Incompressible (IBE) Security



Challenger

Adversary 1

$(msk, mpk) \leftarrow Setup()$ $\xrightarrow{mpk}$

$\xleftarrow{id}$ $\xrightarrow{KeyGen(msk, id)}$

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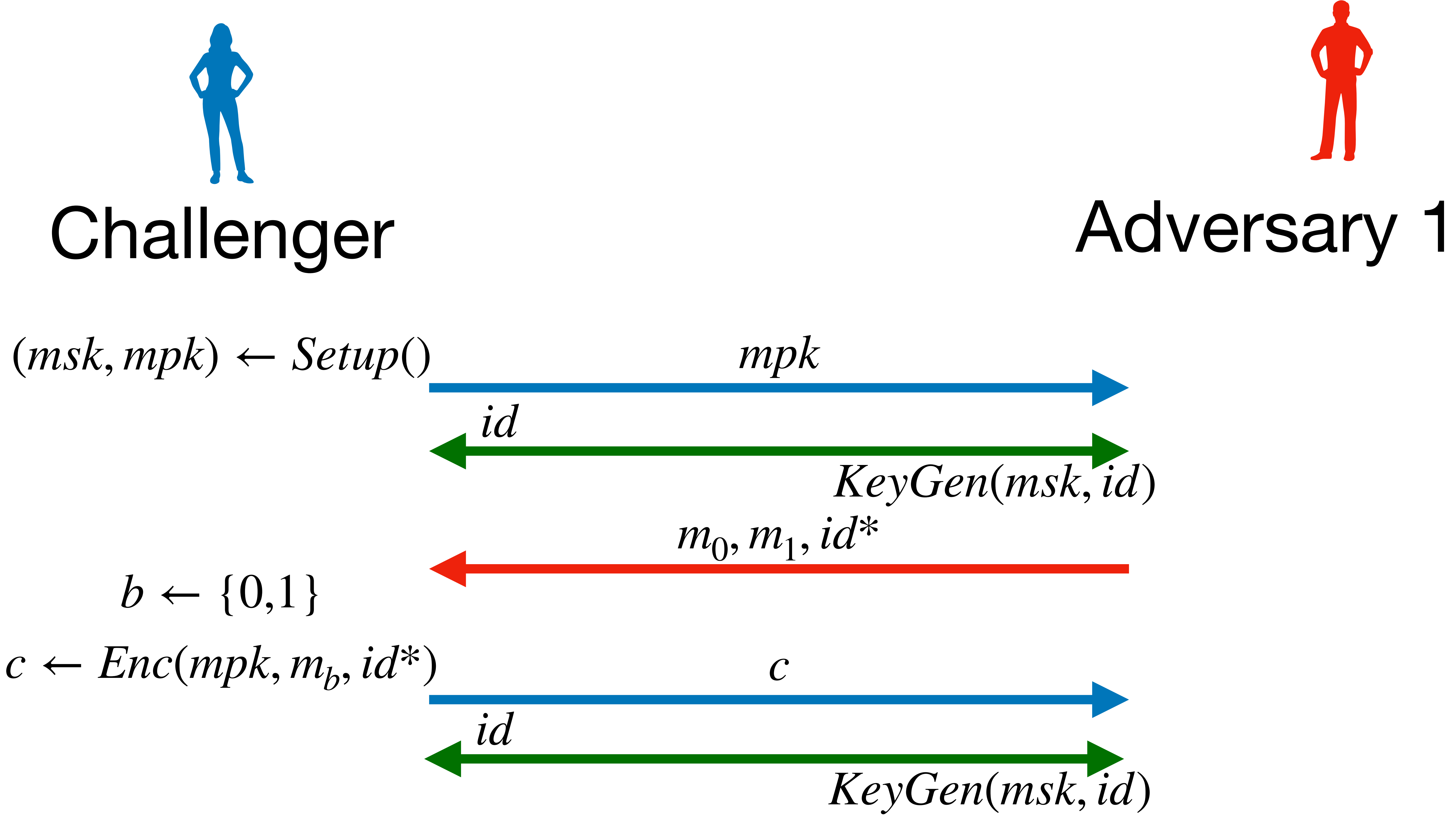
Incompressible (IBE) Security



Challenger

Adversary 1

$(msk, mpk) \leftarrow Setup()$

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id

$KeyGen(msk, id)$

m_0, m_1, id^*

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

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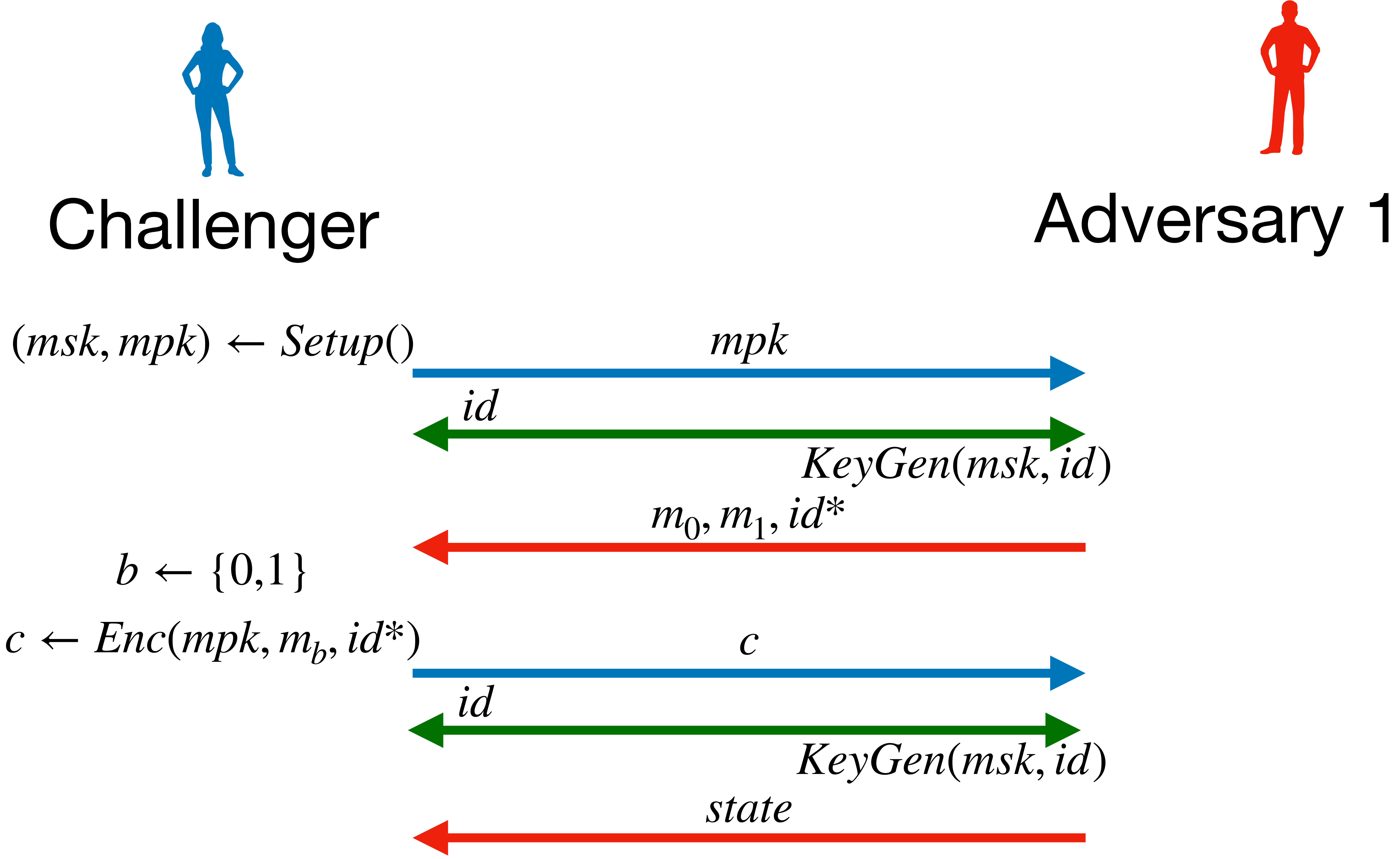
c

id

$KeyGen(msk, id)$

Incompressible (IBE) Security



Challenger

Adversary 1

$(msk, mpk) \leftarrow Setup()$

mpk

id

$KeyGen(msk, id)$

m_0, m_1, id^*

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

$c \leftarrow Enc(mpk, m_b, id^*)$

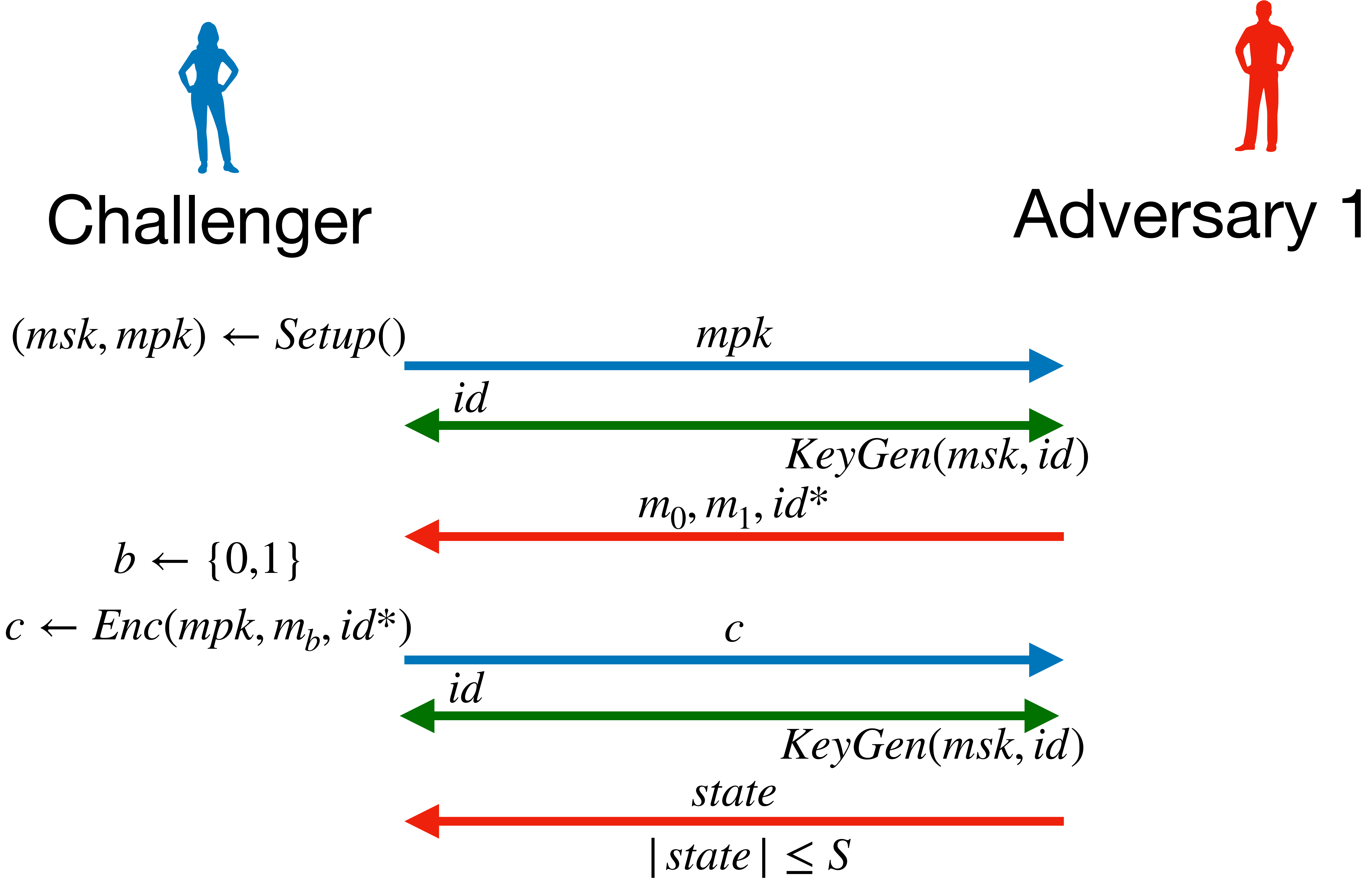
c

id

$KeyGen(msk, id)$

$state$

Incompressible (IBE) Security



Challenger

Adversary 1

$(msk, mpk) \leftarrow Setup()$

mpk

id

$KeyGen(msk, id)$

m_0, m_1, id^*

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

$c \leftarrow Enc(mpk, m_b, id^*)$

c

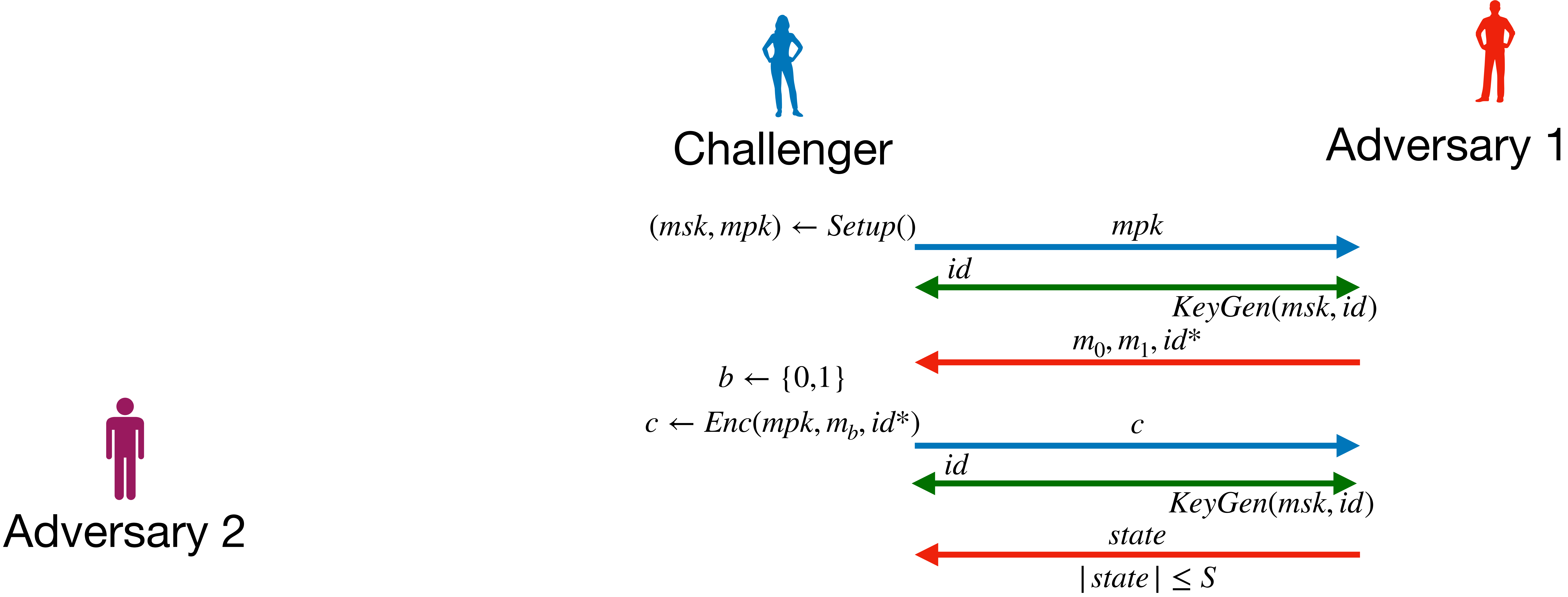
id

$KeyGen(msk, id)$

$state$

$|state| \leq S$

Incompressible (IBE) Security



Challenger

Adversary 1

$(msk, mpk) \leftarrow Setup()$

mpk

id

$KeyGen(msk, id)$

$m_0, m_1, id*$

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

$c \leftarrow Enc(mpk, m_b, id*)$

c

id

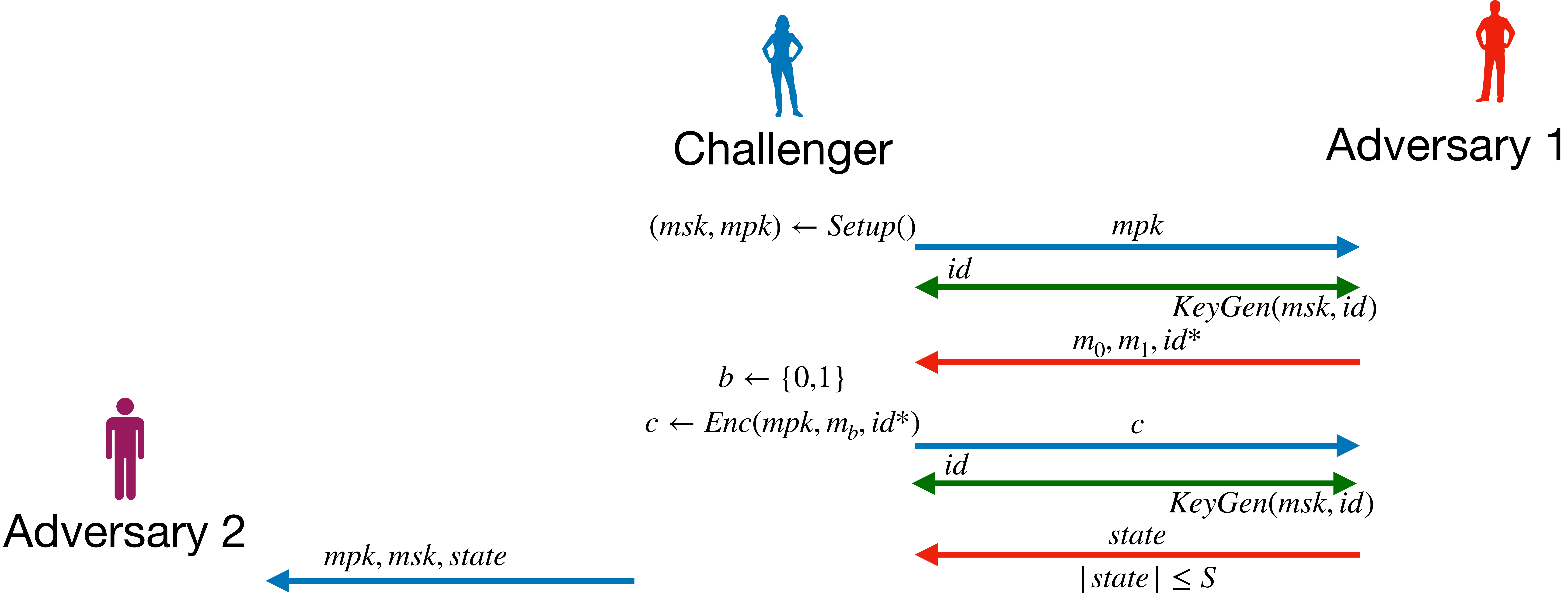
$KeyGen(msk, id)$

$state$

$|state| \leq S$

Adversary 2

Incompressible (IBE) Security



Challenger

Adversary 1

$(msk, mpk) \leftarrow Setup()$

mpk

id

$KeyGen(msk, id)$

m_0, m_1, id^*

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

$c \leftarrow Enc(mpk, m_b, id^*)$

c

id

$KeyGen(msk, id)$

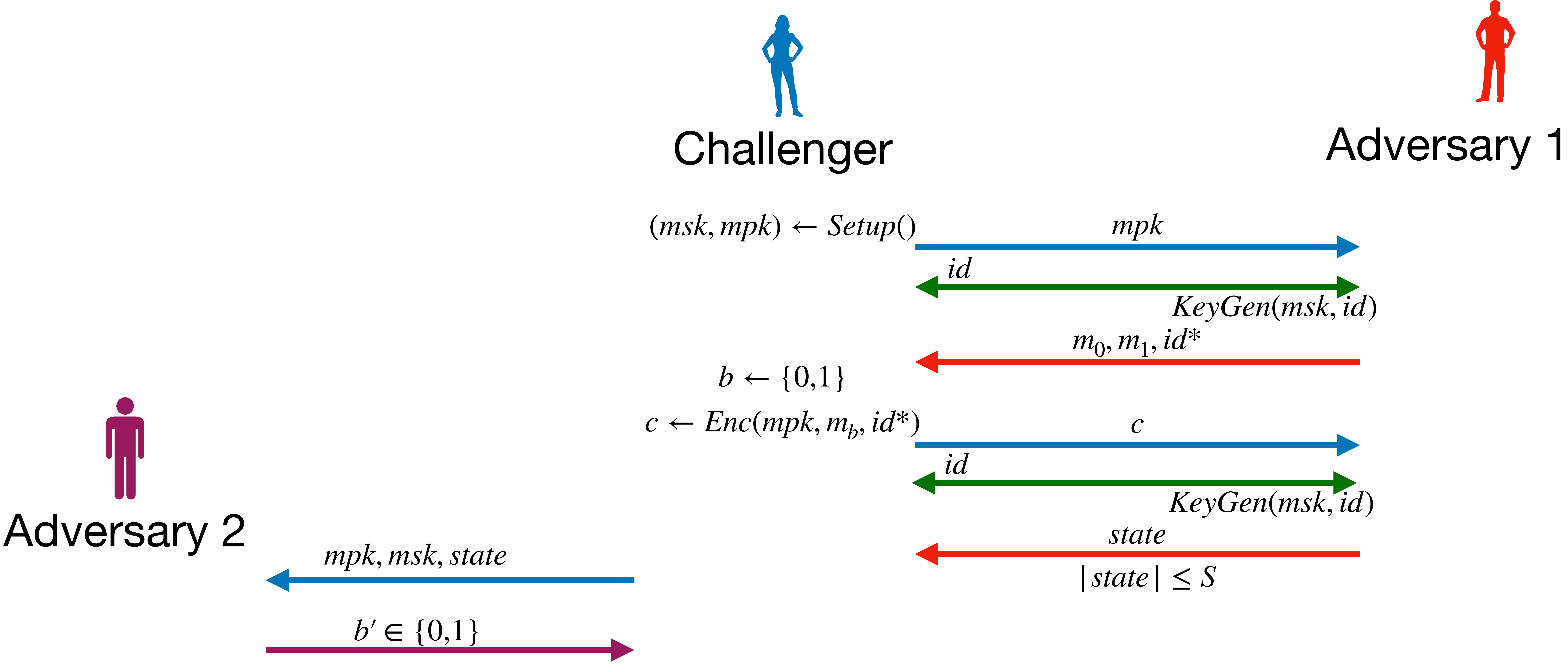
$state$

$|state| \leq S$

Adversary 2

$mpk, msk, state$

Incompressible (IBE) Security



Challenger

Adversary 1

Adversary 2

$(msk, mpk) \leftarrow Setup()$

mpk

id

$KeyGen(msk, id)$

m_0, m_1, id^*

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

$c \leftarrow Enc(mpk, m_b, id^*)$

c

id

$KeyGen(msk, id)$

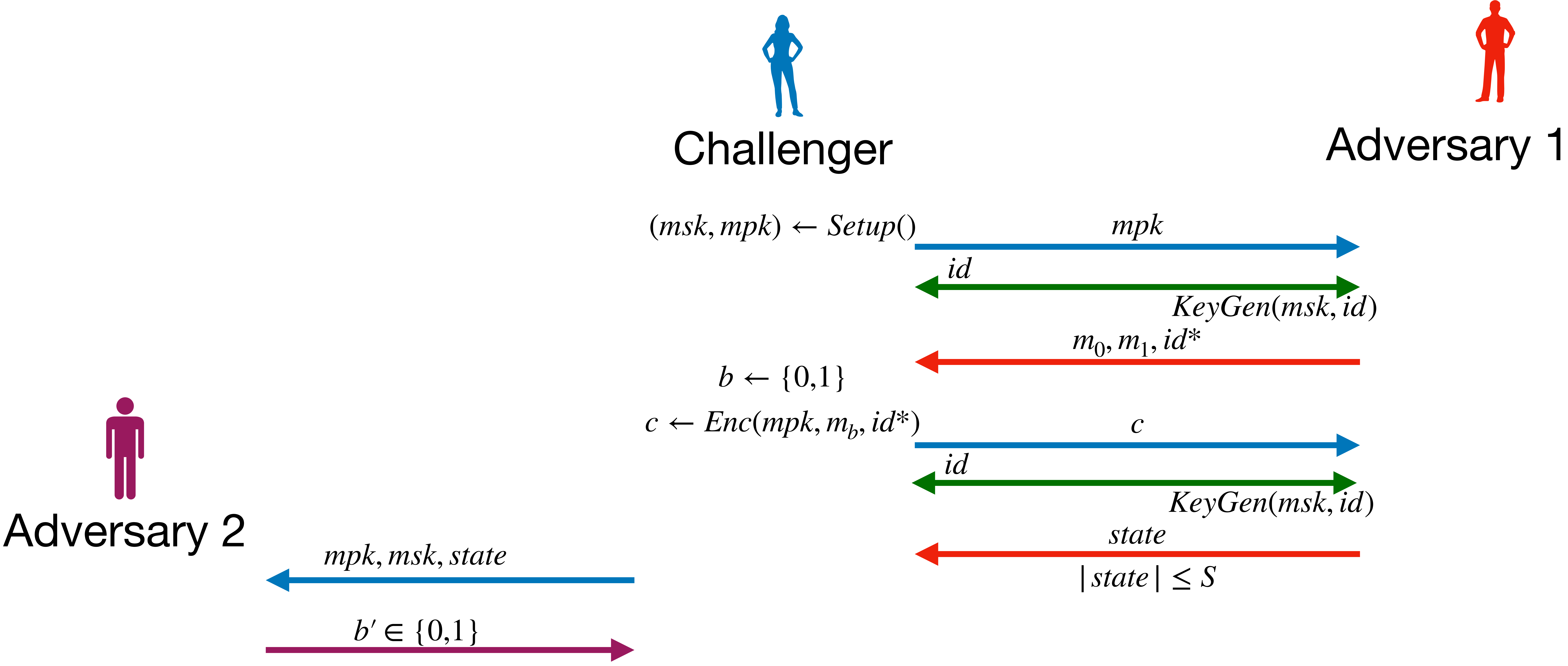
$state$

$|state| \leq S$

$mpk, msk, state$

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

Incompressible (IBE) Security



Challenger

Adversary 1

Adversary 2

$(msk, mpk) \leftarrow Setup()$

mpk

id

$KeyGen(msk, id)$

m_0, m_1, id^*

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

$c \leftarrow Enc(mpk, m_b, id^*)$

c

id

$KeyGen(msk, id)$

$state$

$|state| \leq S$

$mpk, msk, state$

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

Adversaries wins if $b = b'$

Our Results

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- Gave an incompressible IBE scheme where second adversary gets sk_{id*}, i.e., the secret key for the target identity.

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- Replace the PKE in the incompressible PKE construction with IBE.

Functional Encryption

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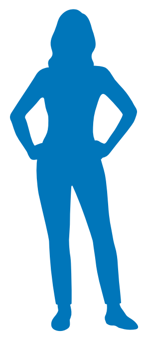
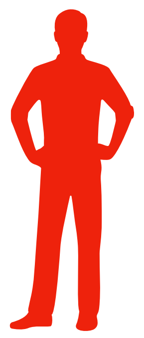
- $Setup()$: Outputs master public and secret key (mpk, msk).
- $Enc(mpk, m)$: Outputs ciphertext c.
- $KeyGen(msk, f)$: Outputs secret key sk_f.
- $Dec(sk_f, c)$: Outputs $f(m)$ or error.

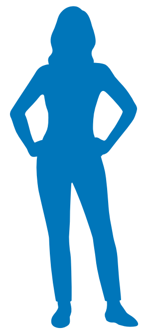
FE Security

FE Security

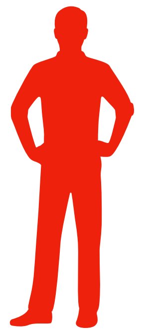




FE Security

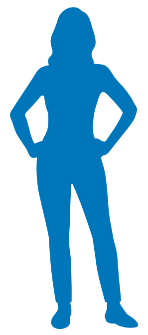


Challenger

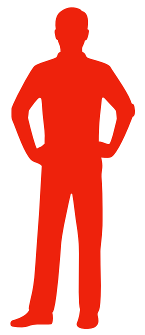


Adversary

FE Security



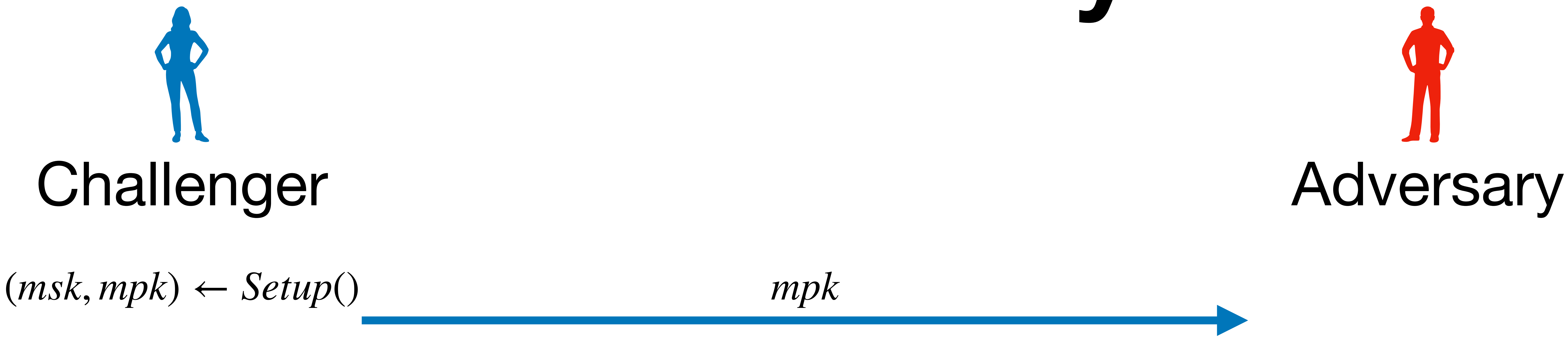
Challenger



Adversary

$(msk, mpk) \leftarrow Setup()$

FE Security



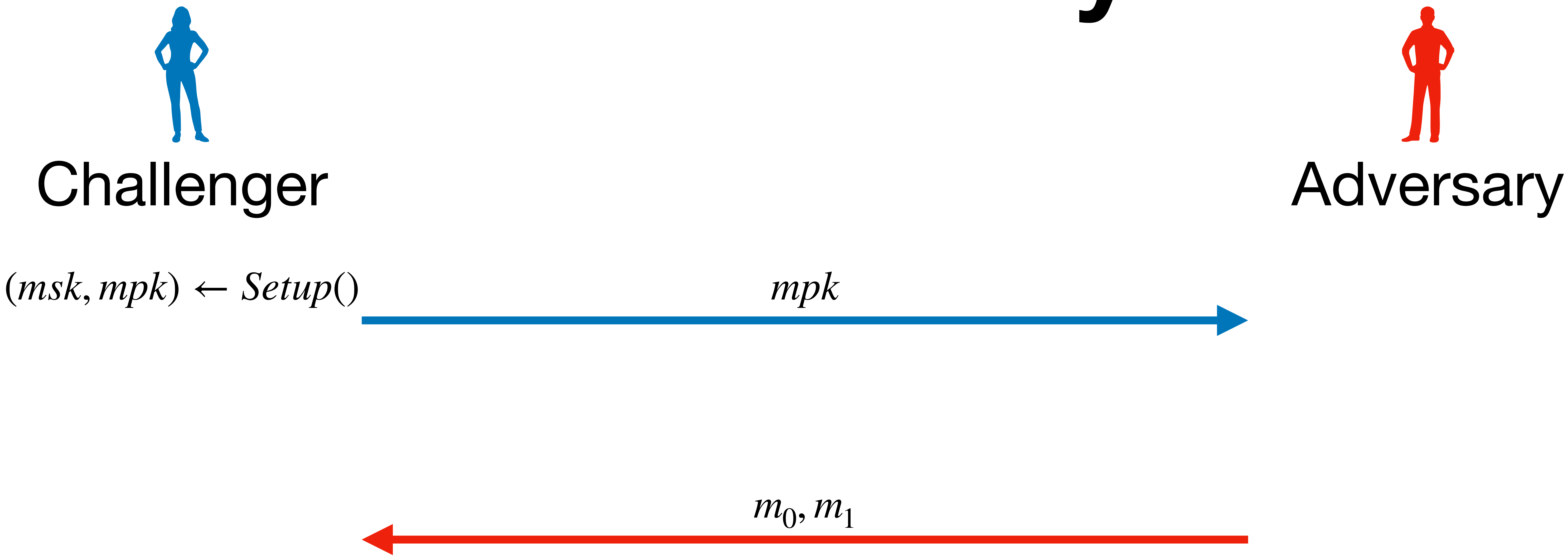
Challenger

Adversary

$(msk, mpk) \leftarrow Setup()$

mpk

FE Security



Challenger

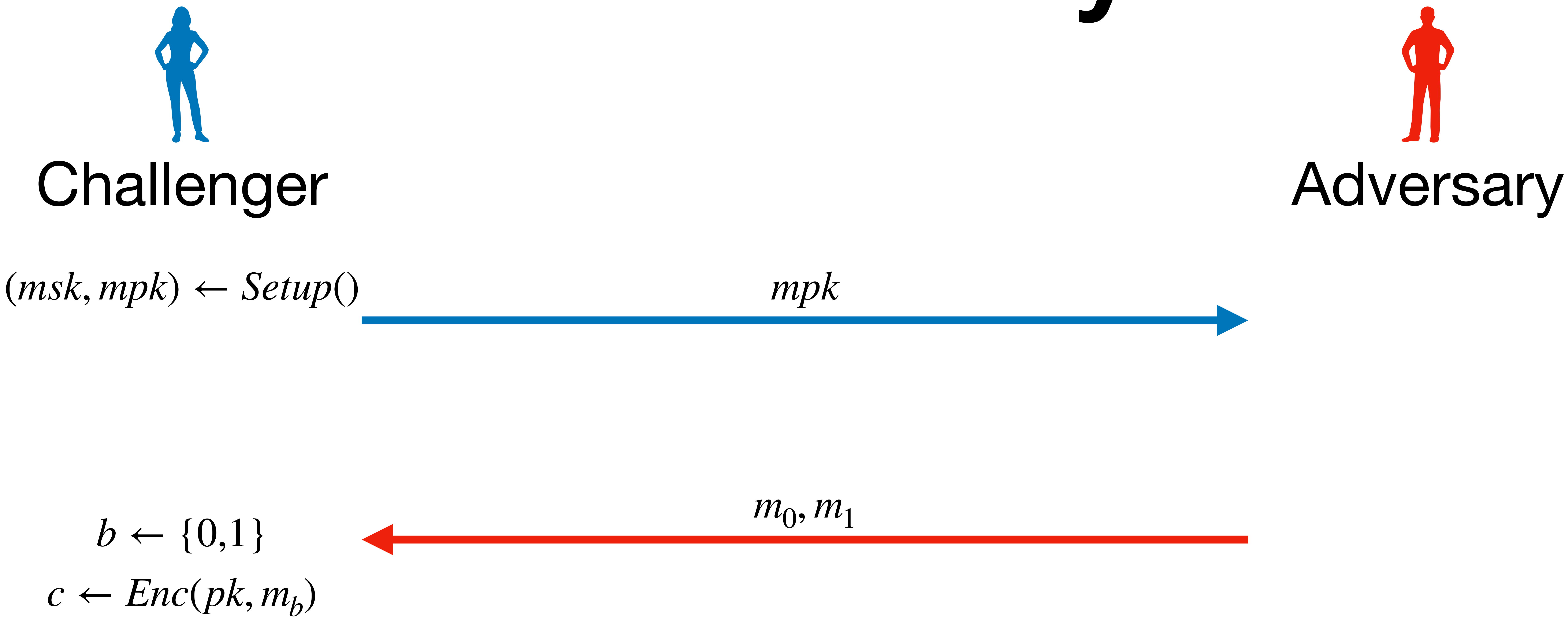
Adversary

$(msk, mpk) \leftarrow Setup()$

mpk

m_0, m_1

FE Security



Challenger

Adversary

$(msk, mpk) \leftarrow Setup()$

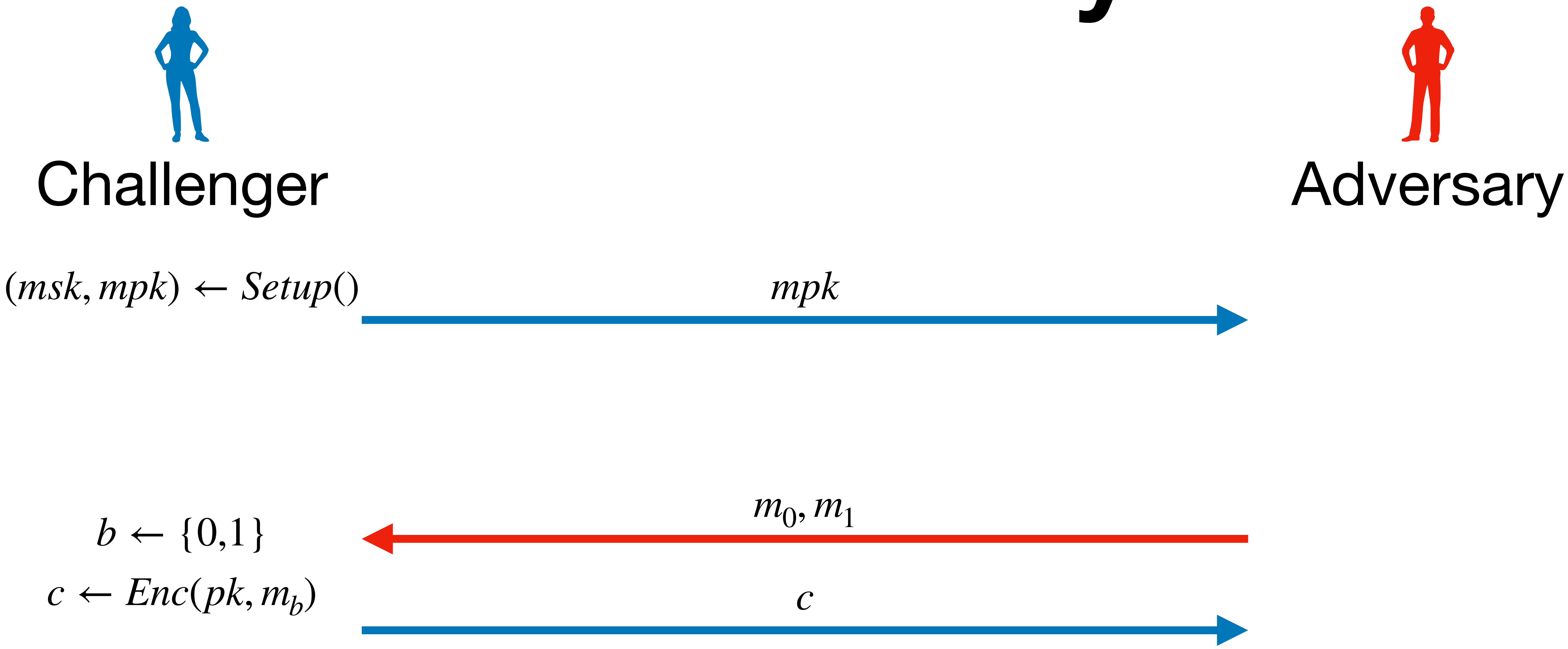
mpk

m_0, m_1

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

$c \leftarrow Enc(pk, m_b)$

FE Security



Challenger

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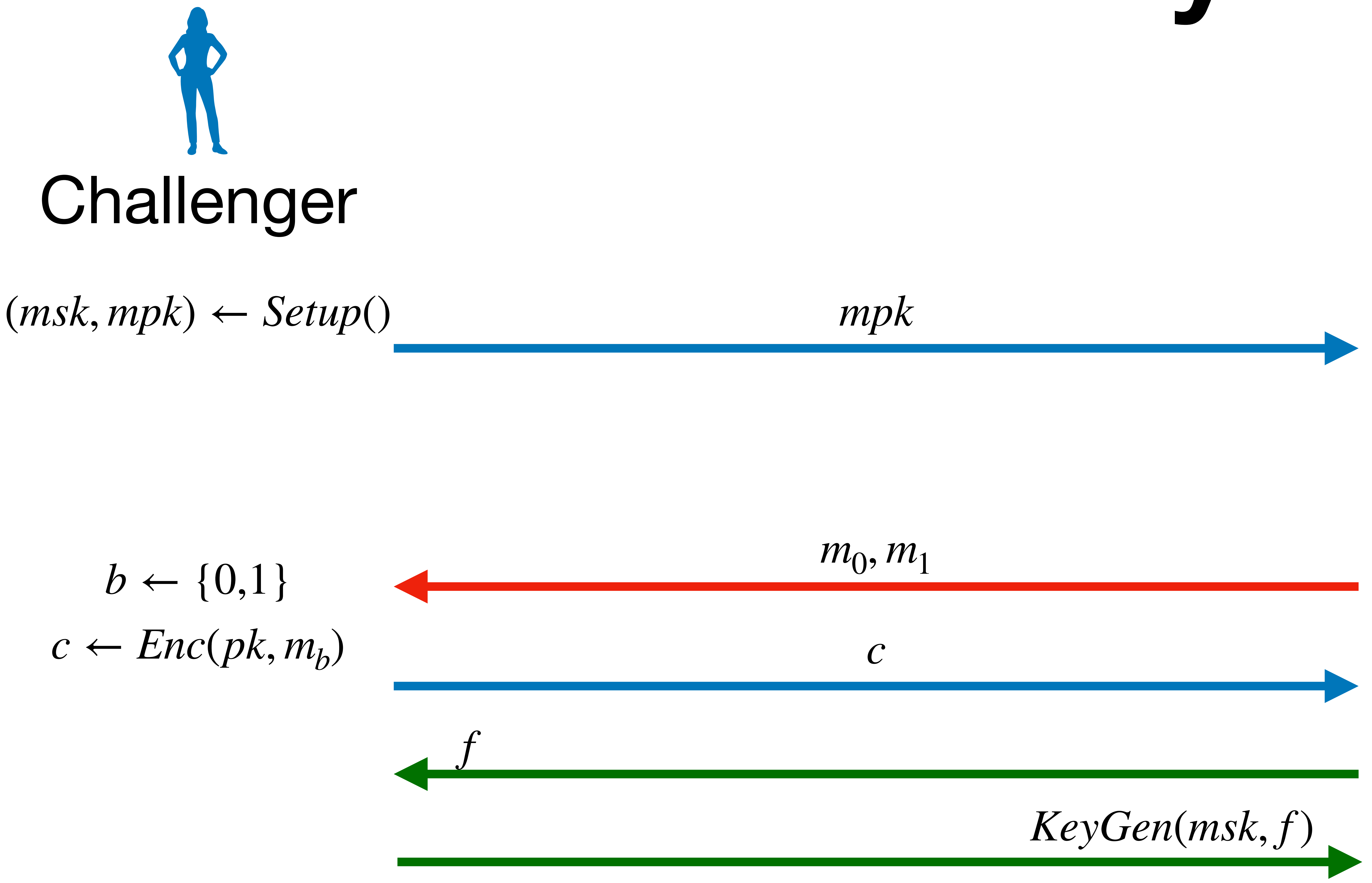
c

FE Security



Challenger

Adversary

$(msk, mpk) \leftarrow Setup()$

mpk

m_0, m_1

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

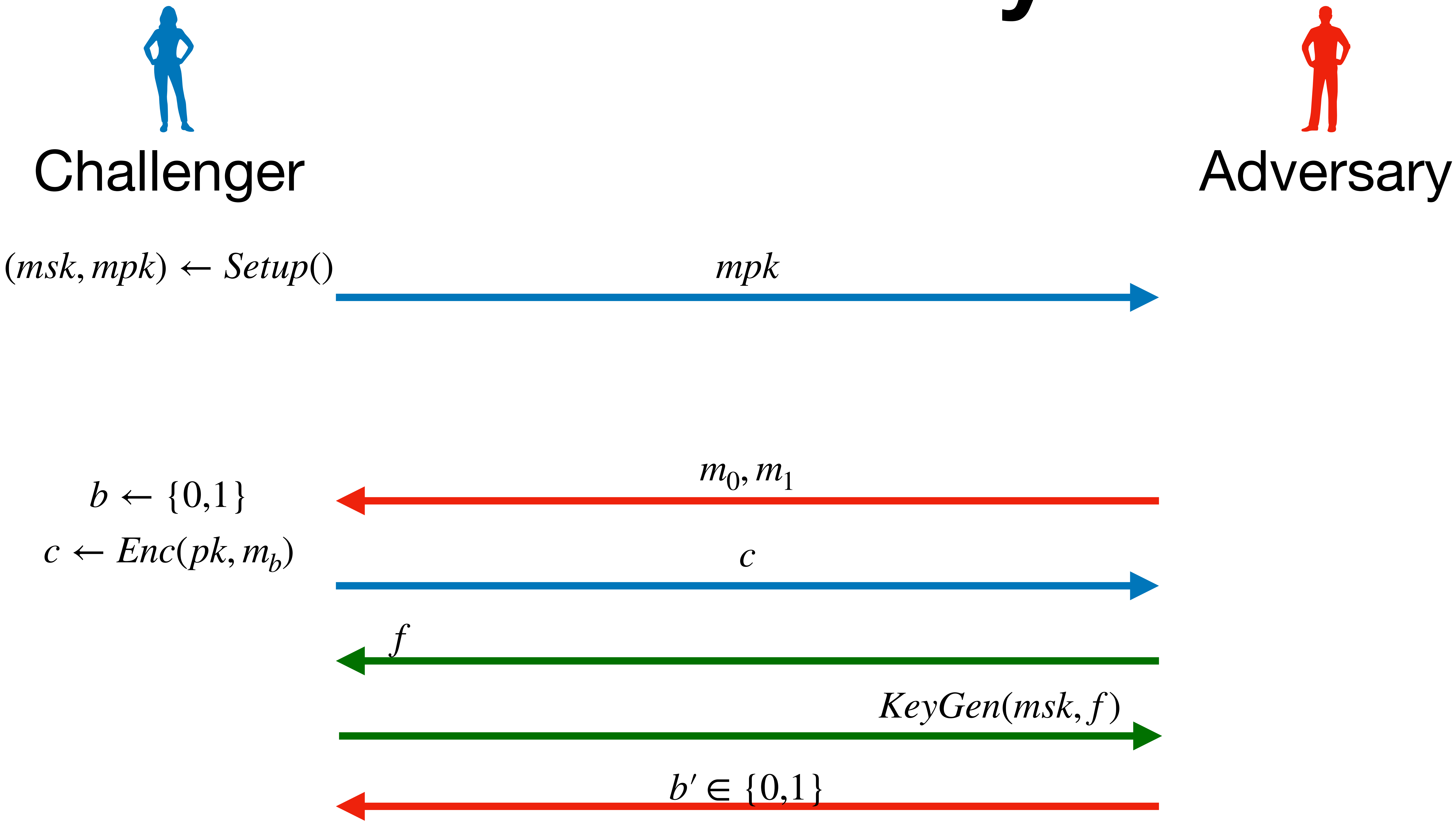
$c \leftarrow Enc(pk, m_b)$

c

f

$KeyGen(msk, f)$

FE Security



Challenger

Adversary

$(msk, mpk) \leftarrow Setup()$

mpk

m_0, m_1

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

$c \leftarrow Enc(pk, m_b)$

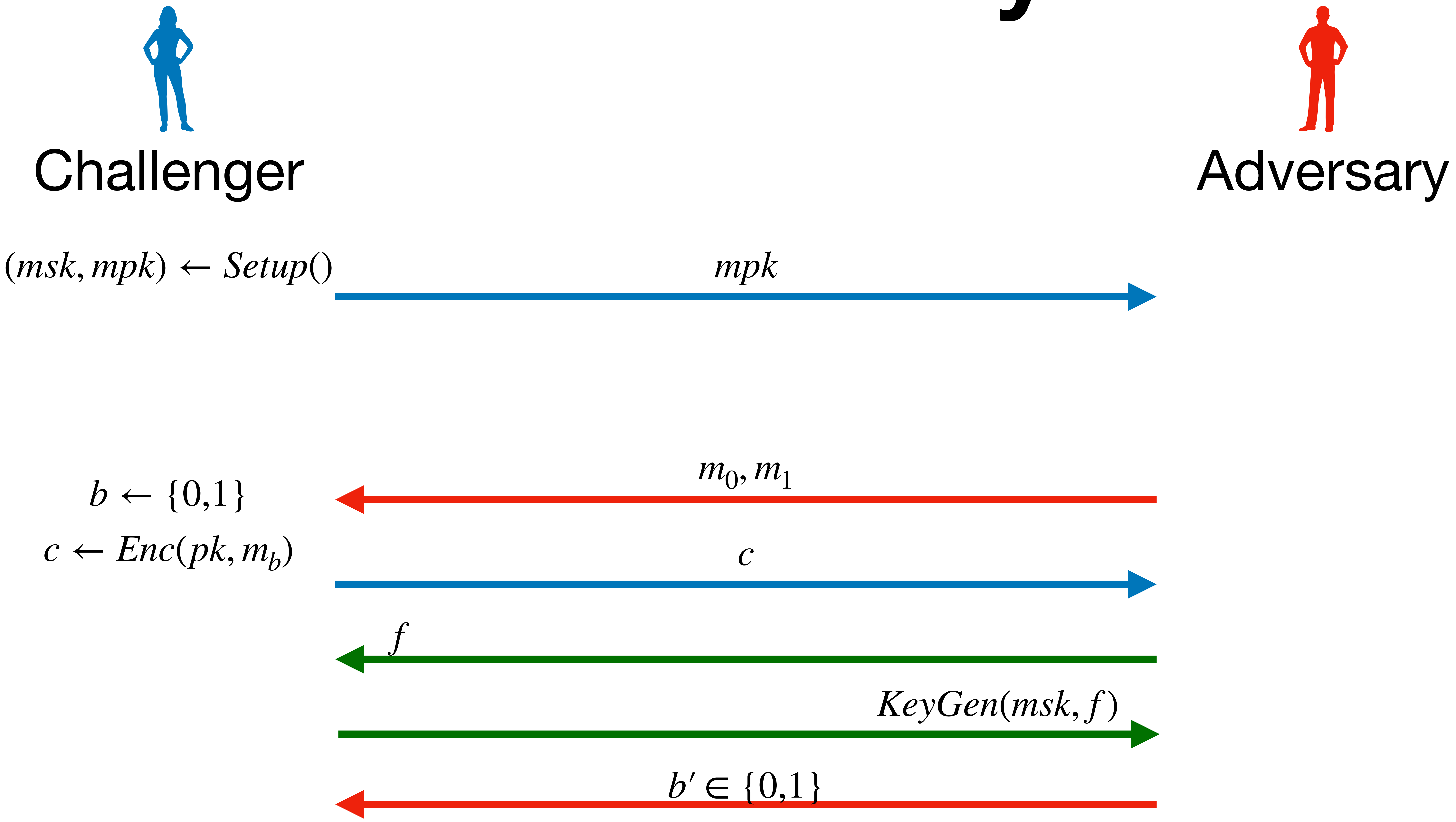
c

f

$KeyGen(msk, f)$

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

FE Security



Challenger

Adversary

$(msk, mpk) \leftarrow Setup()$

mpk

m_0, m_1

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

$c \leftarrow Enc(pk, m_b)$

c

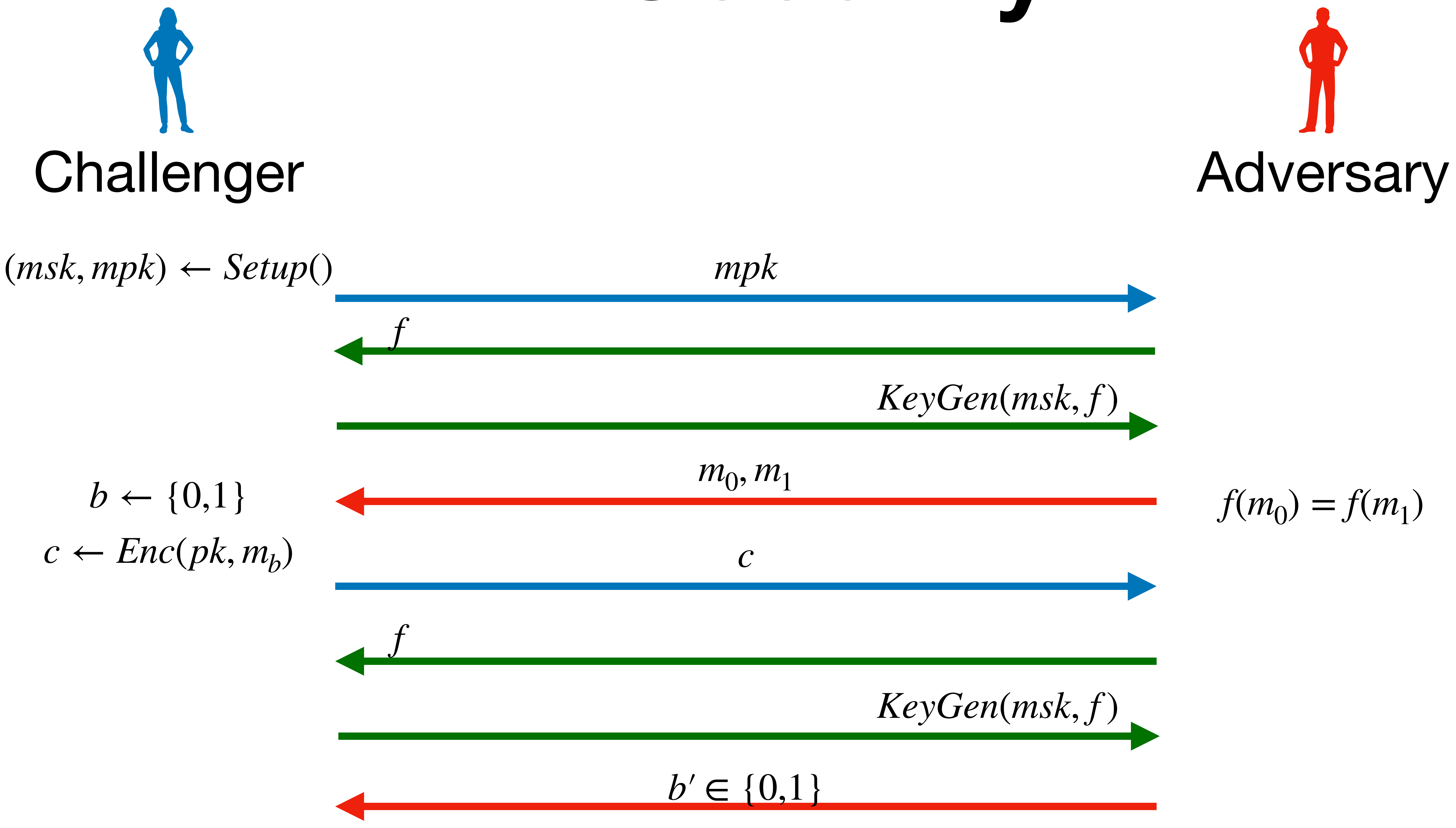
f

$KeyGen(msk, f)$

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

Adversary wins if $b = b'$

FE Security



Challenger

Adversary

$(msk, mpk) \leftarrow Setup()$

mpk

f

$KeyGen(msk, f)$

m_0, m_1

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

$f(m_0) = f(m_1)$

$c \leftarrow Enc(pk, m_b)$

c

f

$KeyGen(msk, f)$

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

Adversary wins if $b = b'$

Strong Incompressible (FE) Security

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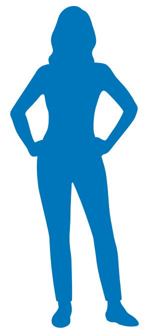
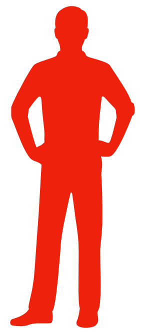
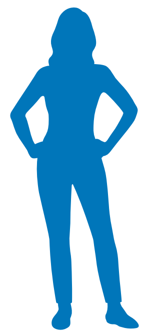


Challenger

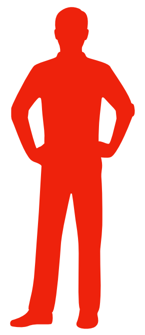


Adversary 1

Strong Incompressible (FE) Security



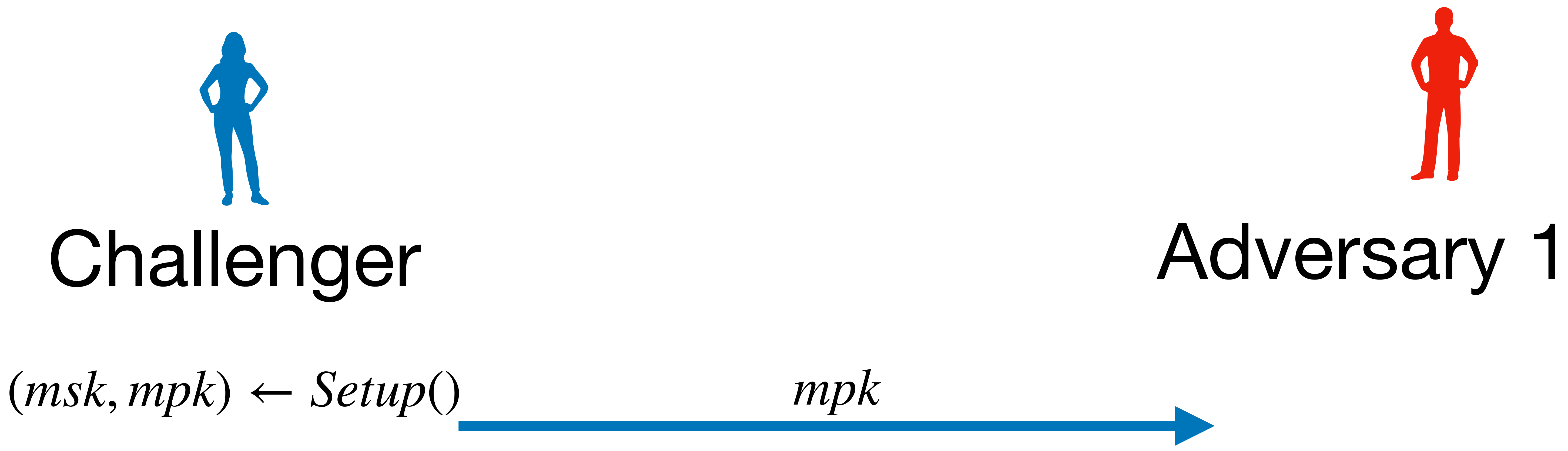
Challenger



Adversary 1

$$(msk, mpk) \leftarrow Setup()$$

Strong Incompressible (FE) Security



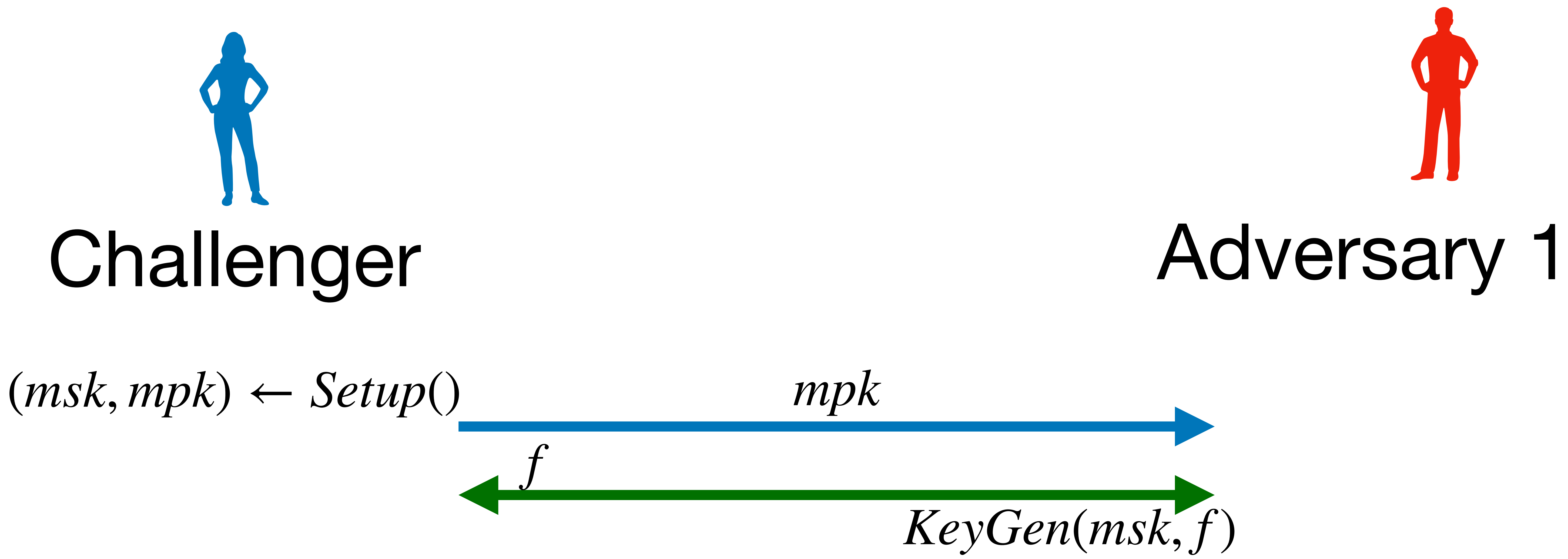
Challenger

Adversary 1

$(msk, mpk) \leftarrow Setup()$

$\xrightarrow{mpk}$

Strong Incompressible (FE) Security



Challenger

Adversary 1

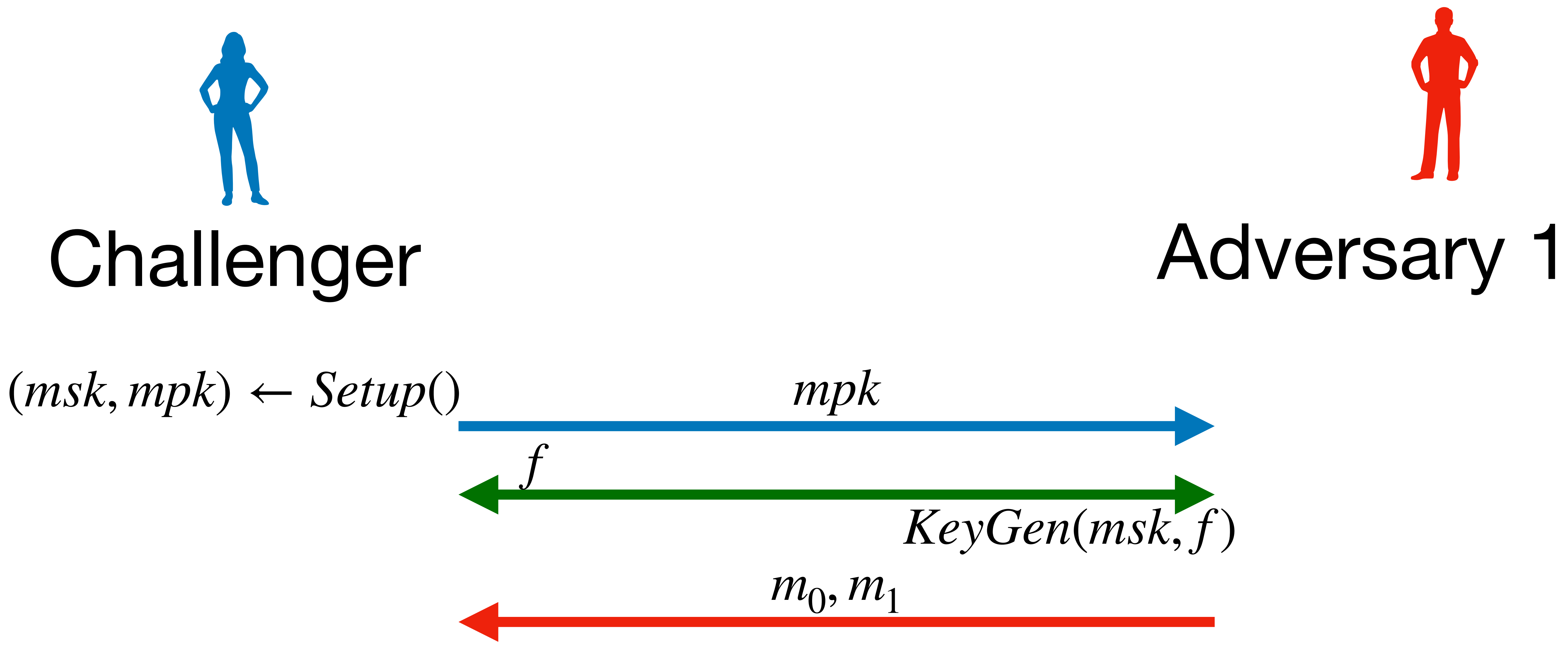
$(msk, mpk) \leftarrow Setup()$

mpk

f

$KeyGen(msk, f)$

Strong Incompressible (FE) Security



Challenger

Adversary 1

$(msk, mpk) \leftarrow Setup()$

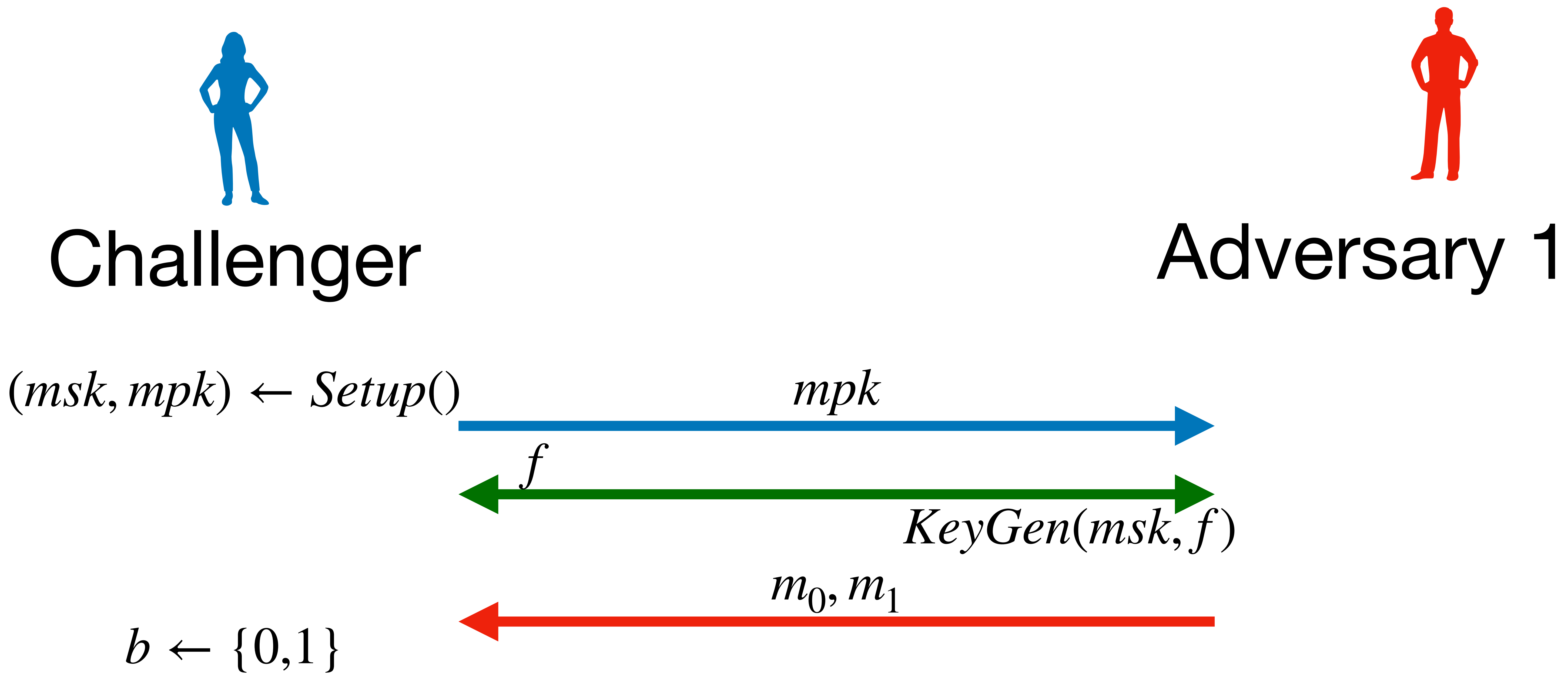
mpk

f

$KeyGen(msk, f)$

m_0, m_1

Strong Incompressible (FE) Security



Challenger

Adversary 1

$(msk, mpk) \leftarrow Setup()$

mpk

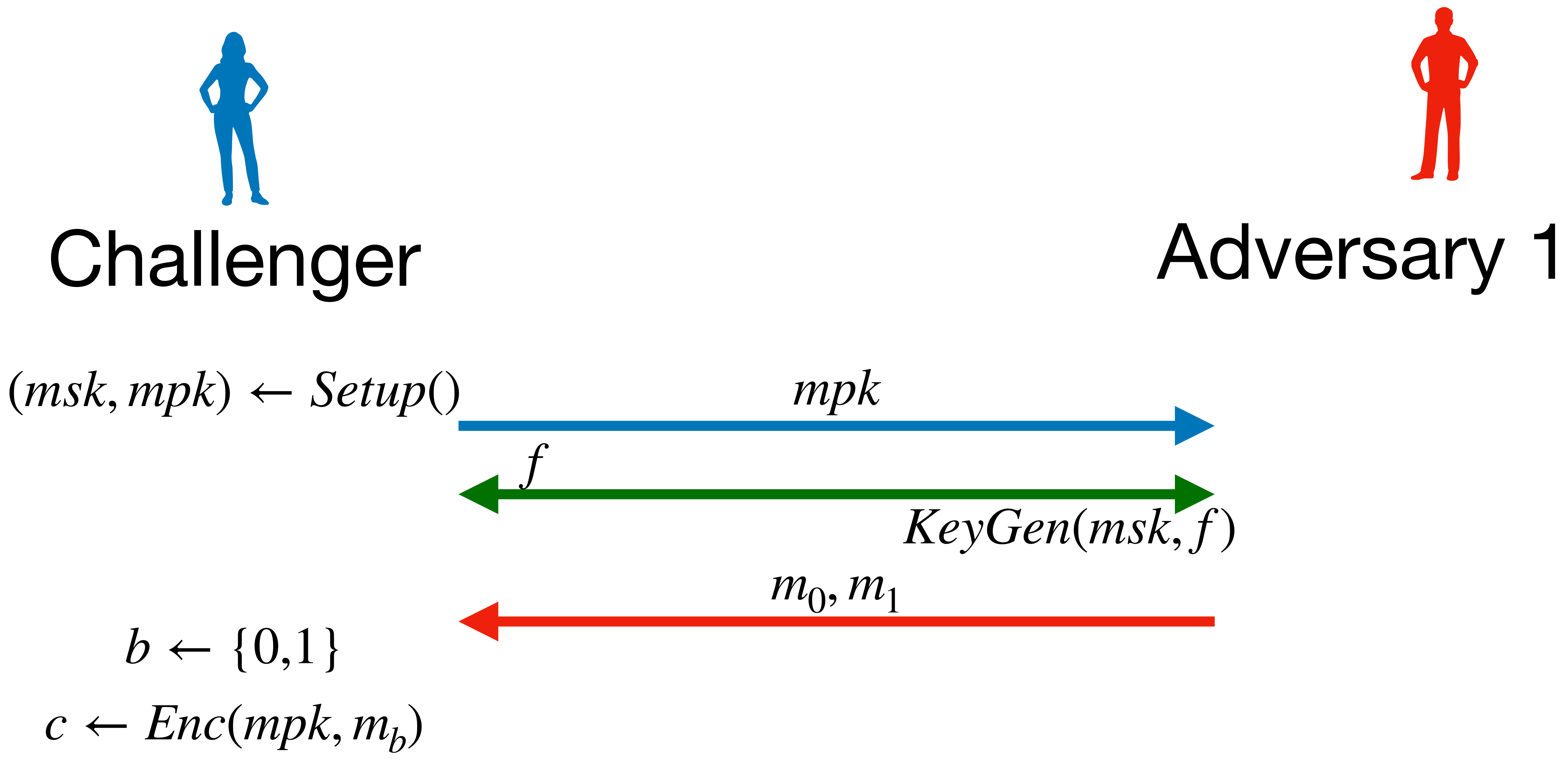
f

$KeyGen(msk, f)$

m_0, m_1

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

Strong Incompressible (FE) Security

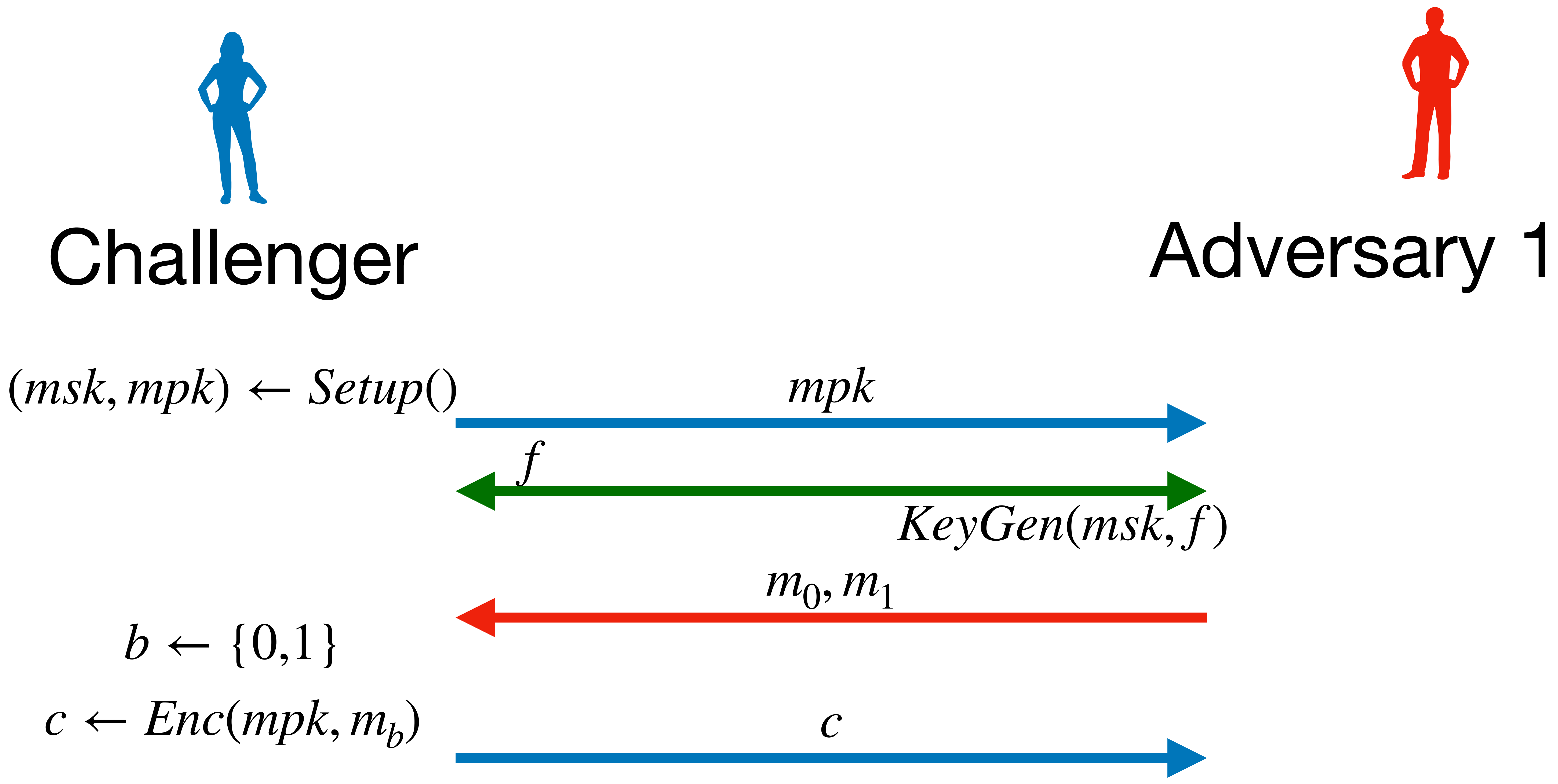


$(msk, mpk) \leftarrow Setup()$

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

$c \leftarrow Enc(mpk, m_b)$

Strong Incompressible (FE) Security



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m_0, m_1

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

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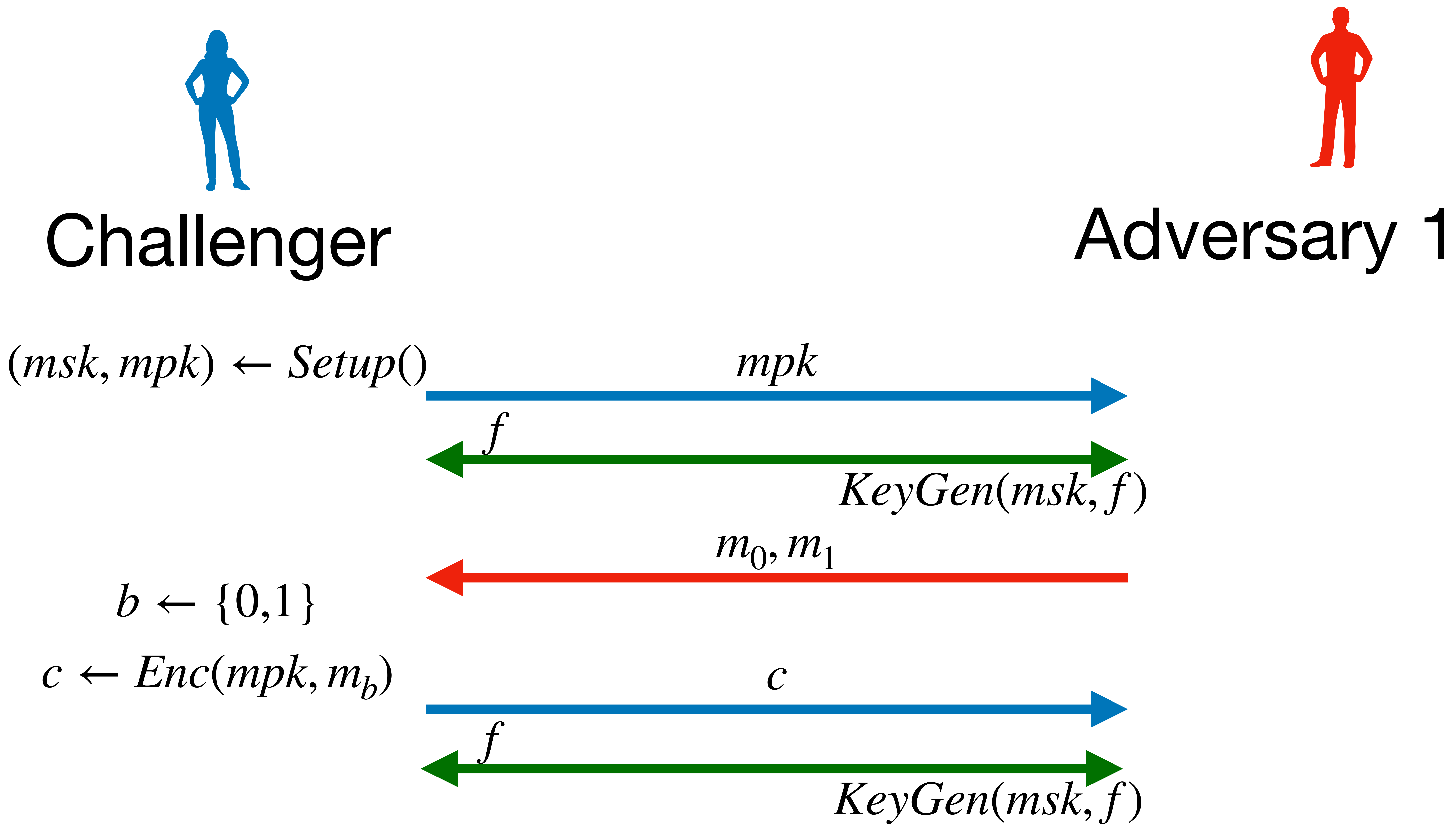
c

Strong Incompressible (FE) Security



Challenger

Adversary 1

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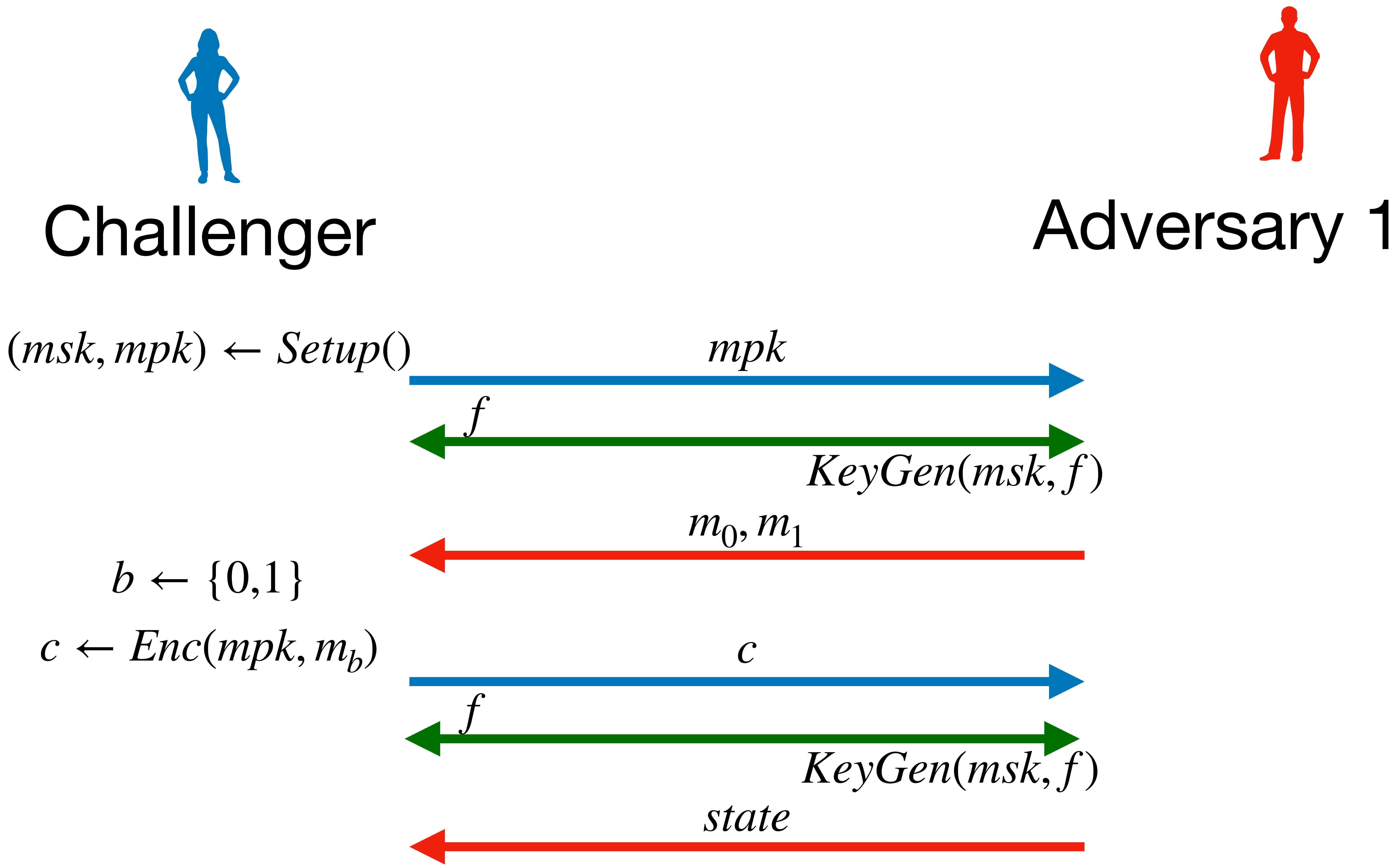
$KeyGen(msk, f)$

Strong Incompressible (FE) Security



Challenger

Adversary 1

$(msk, mpk) \leftarrow Setup()$

mpk

f

$KeyGen(msk, f)$

m_0, m_1

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

$c \leftarrow Enc(mpk, m_b)$

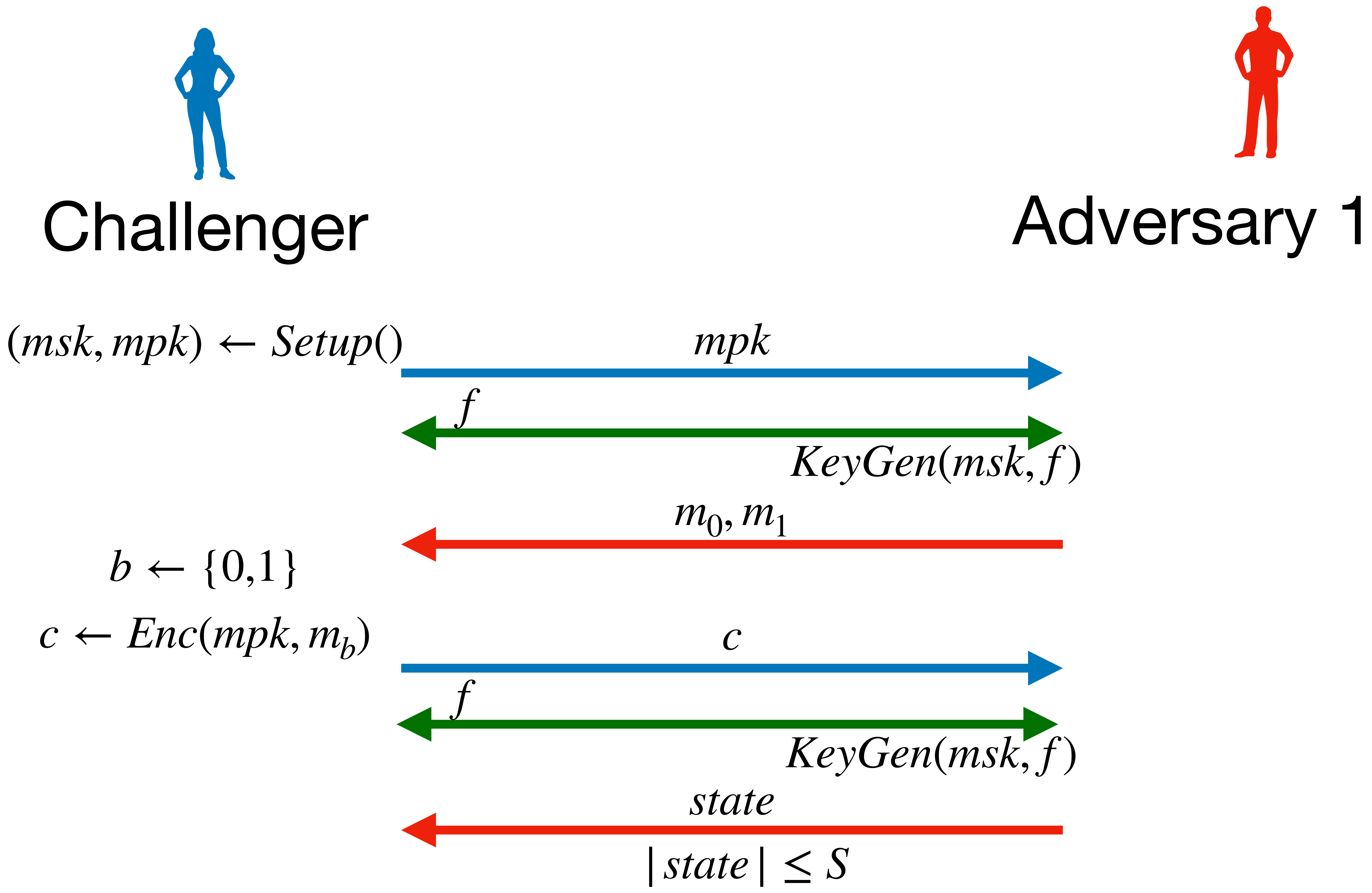
c

f

$KeyGen(msk, f)$

$state$

Strong Incompressible (FE) Security



Challenger

Adversary 1

$(msk, mpk) \leftarrow Setup()$

mpk

f

$KeyGen(msk, f)$

m_0, m_1

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

$c \leftarrow Enc(mpk, m_b)$

c

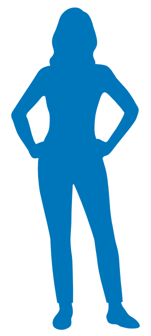
f

$KeyGen(msk, f)$

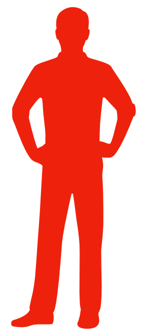
$state$

$|state| \leq S$

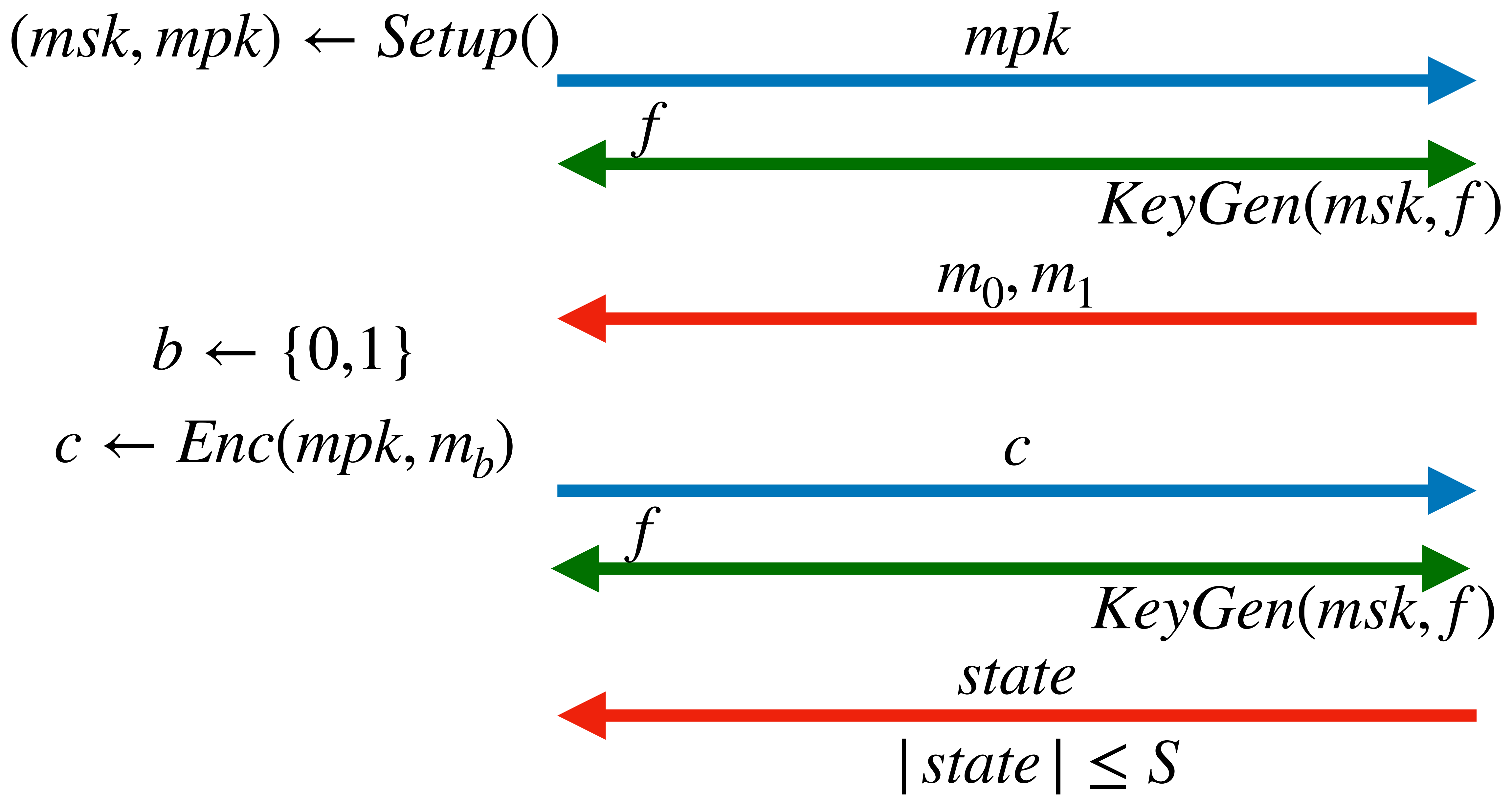
Strong Incompressible (FE) Security



Challenger



Adversary 1



$(msk, mpk) \leftarrow Setup()$

mpk

f

$KeyGen(msk, f)$

m_0, m_1

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

$c \leftarrow Enc(mpk, m_b)$

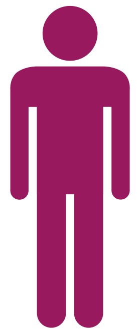
c

f

$KeyGen(msk, f)$

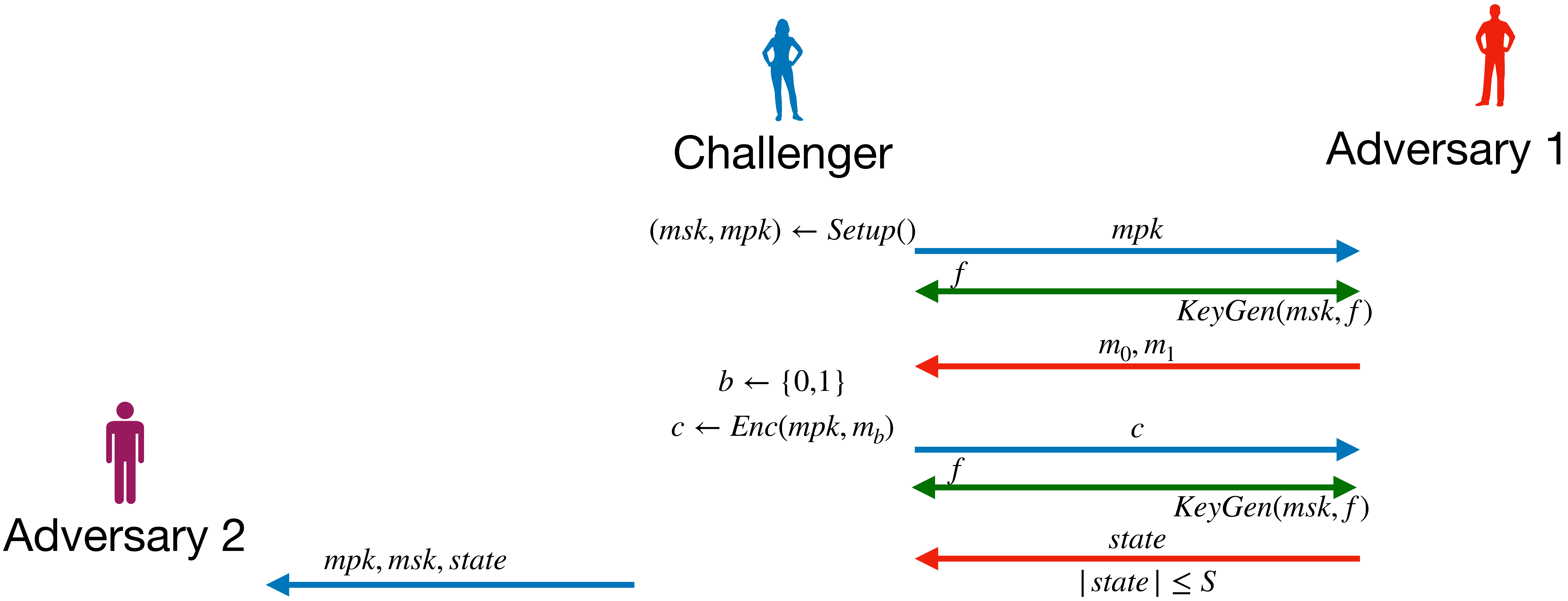
$state$

$|state| \leq S$



Adversary 2

Strong Incompressible (FE) Security



Challenger

Adversary 1

Adversary 2

$(msk, mpk) \leftarrow Setup()$

mpk

f

$KeyGen(msk, f)$

m_0, m_1

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

$c \leftarrow Enc(mpk, m_b)$

c

f

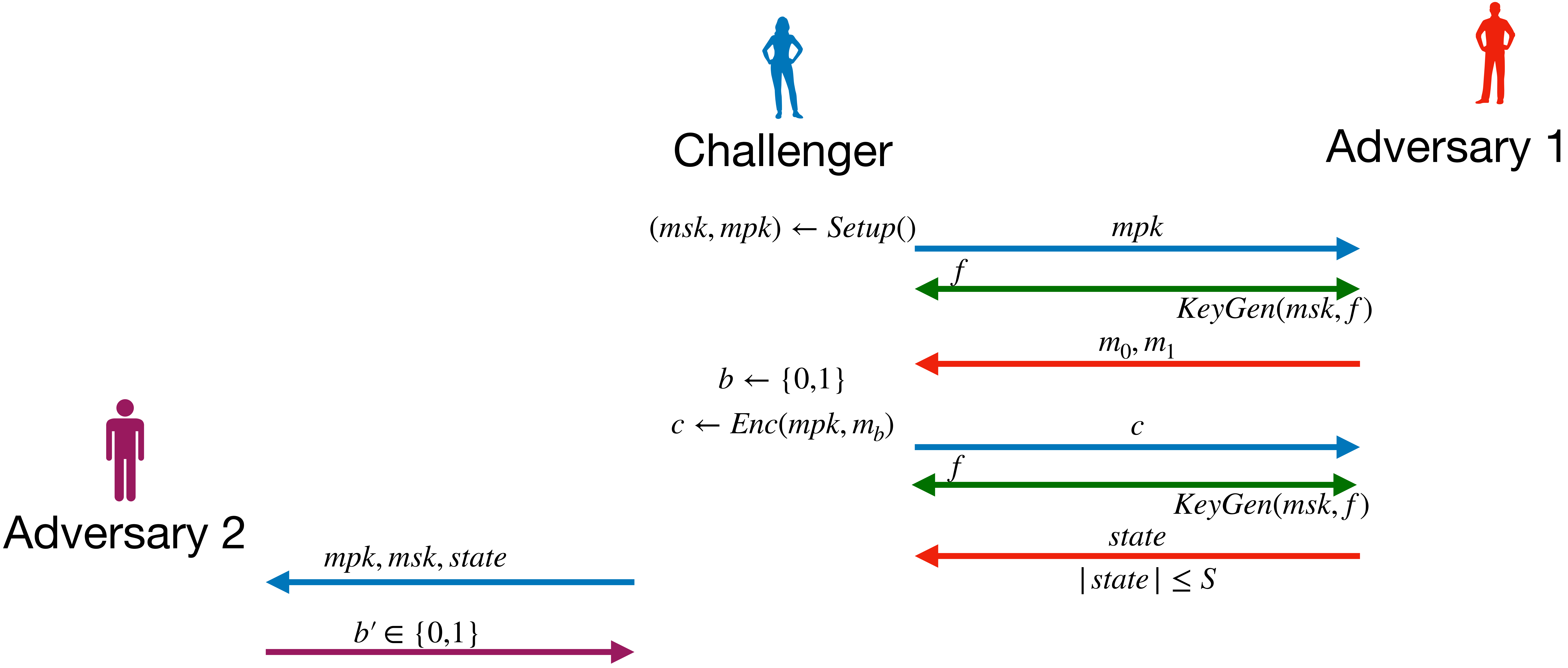
$KeyGen(msk, f)$

$state$

$|state| \leq S$

$mpk, msk, state$

Strong Incompressible (FE) Security



Challenger

Adversary 1

Adversary 2

$(msk, mpk) \leftarrow Setup()$

mpk

f

$KeyGen(msk, f)$

m_0, m_1

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

$c \leftarrow Enc(mpk, m_b)$

c

f

$KeyGen(msk, f)$

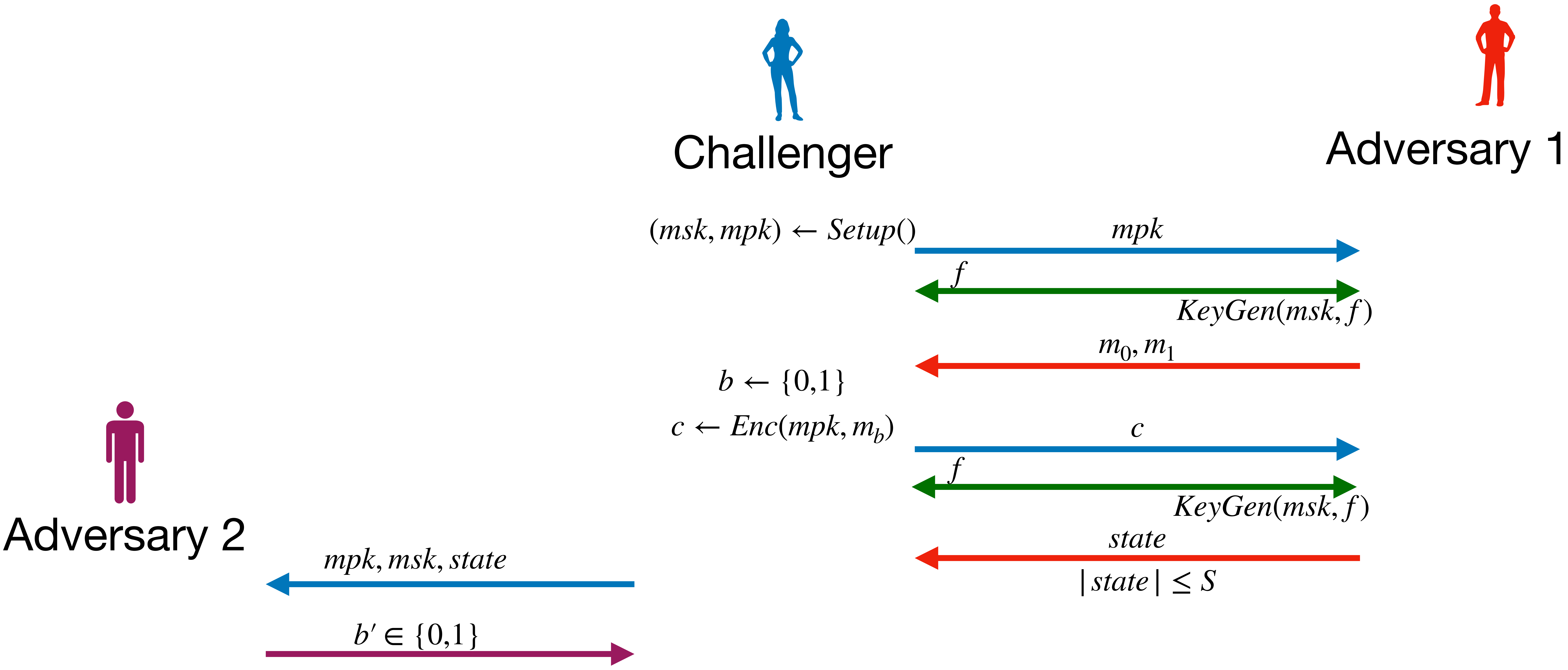
$state$

$|state| \leq S$

$mpk, msk, state$

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

Strong Incompressible (FE) Security



Challenger

Adversary 1

Adversary 2

$(msk, mpk) \leftarrow Setup()$

mpk

f

$KeyGen(msk, f)$

m_0, m_1

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

$c \leftarrow Enc(mpk, m_b)$

c

f

$KeyGen(msk, f)$

$state$

$|state| \leq S$

$mpk, msk, state$

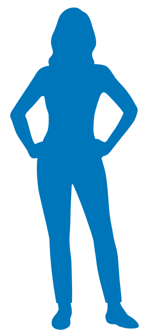
$b' \in \{0,1\}$

Adversaries wins if $b = b'$

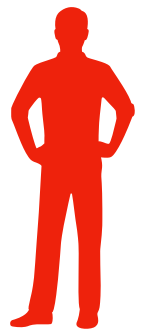
Semi-Strong Incompressible (FE) Security

Semi-Strong Incompressible (FE) Security

Semi-Strong Incompressible (FE) Security

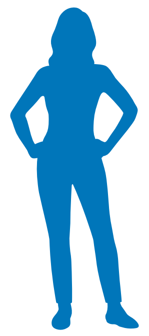


Challenger



Adversary 1

Semi-Strong Incompressible (FE) Security



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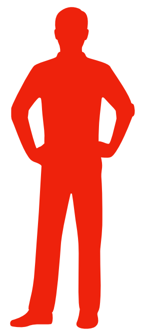
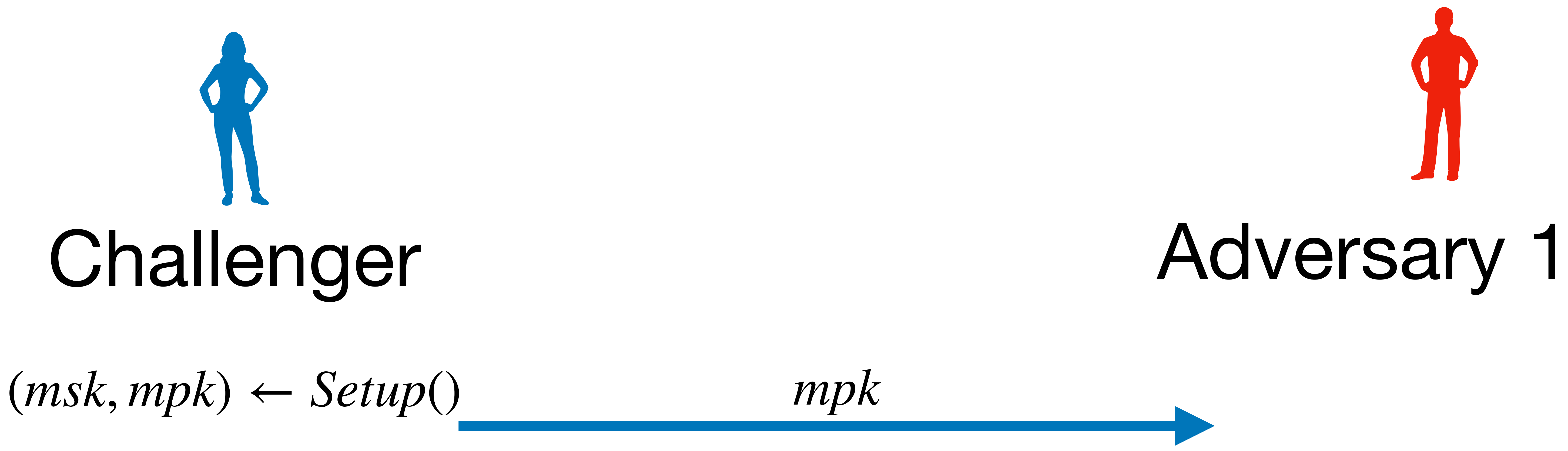


Adversary 1

$$(msk, mpk) \leftarrow Setup()$$

Semi-Strong Incompressible (FE) Security



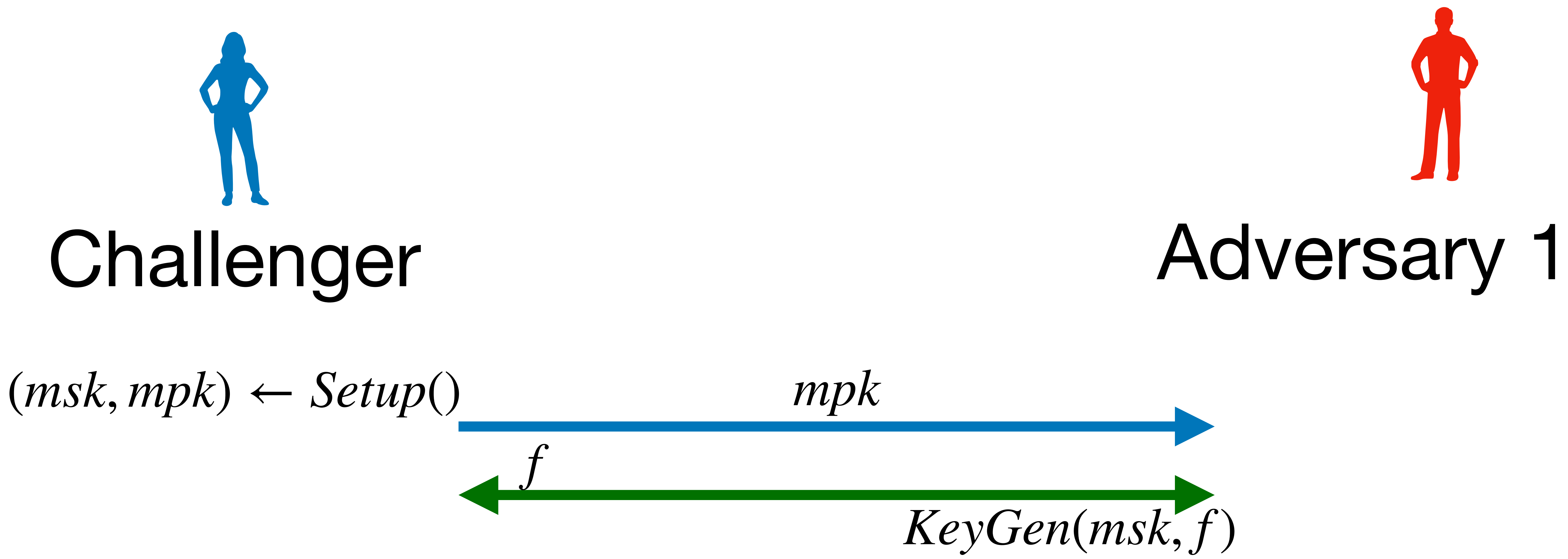
Challenger

Adversary 1

$(msk, mpk) \leftarrow Setup()$

mpk

Semi-Strong Incompressible (FE) Security



Challenger

Adversary 1

$(msk, mpk) \leftarrow Setup()$

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f

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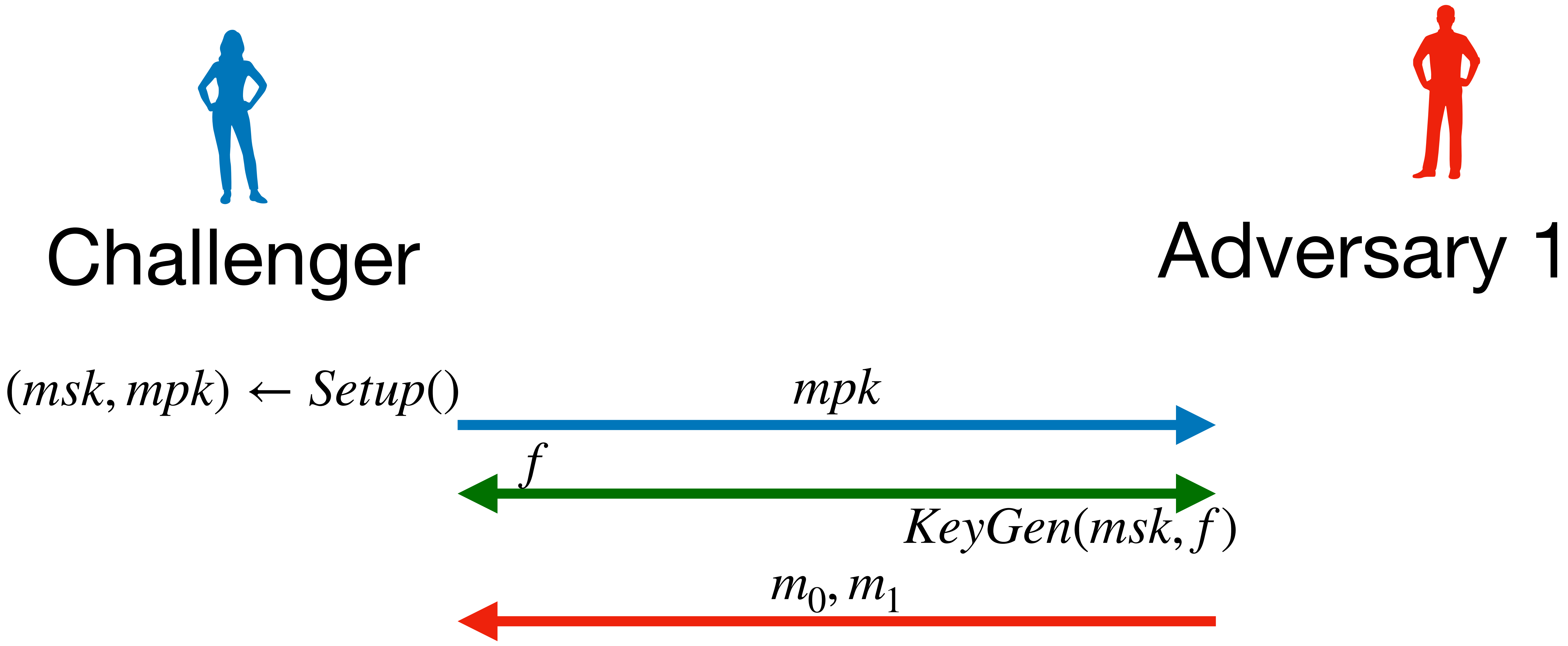
Semi-Strong Incompressible (FE) Security



Challenger

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f

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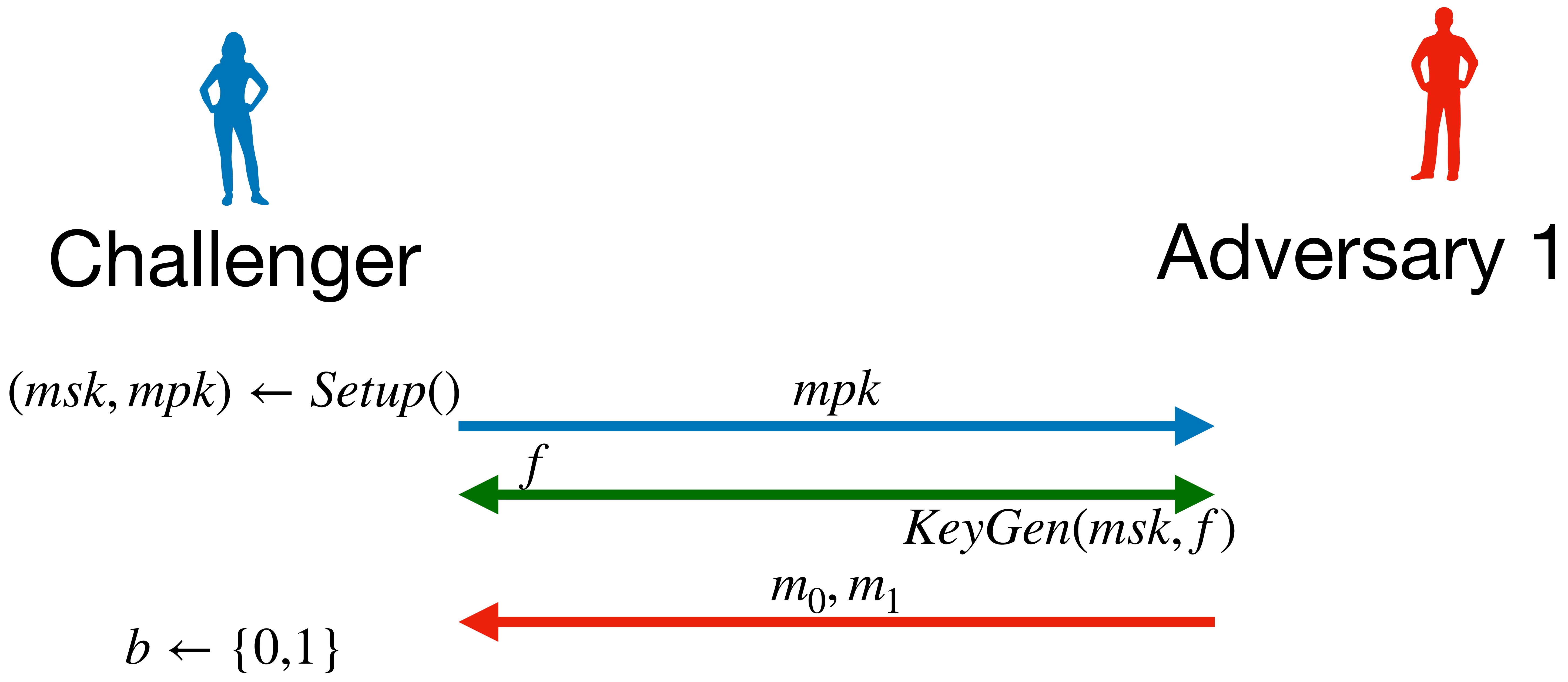
m_0, m_1

Semi-Strong Incompressible (FE) Security



Challenger

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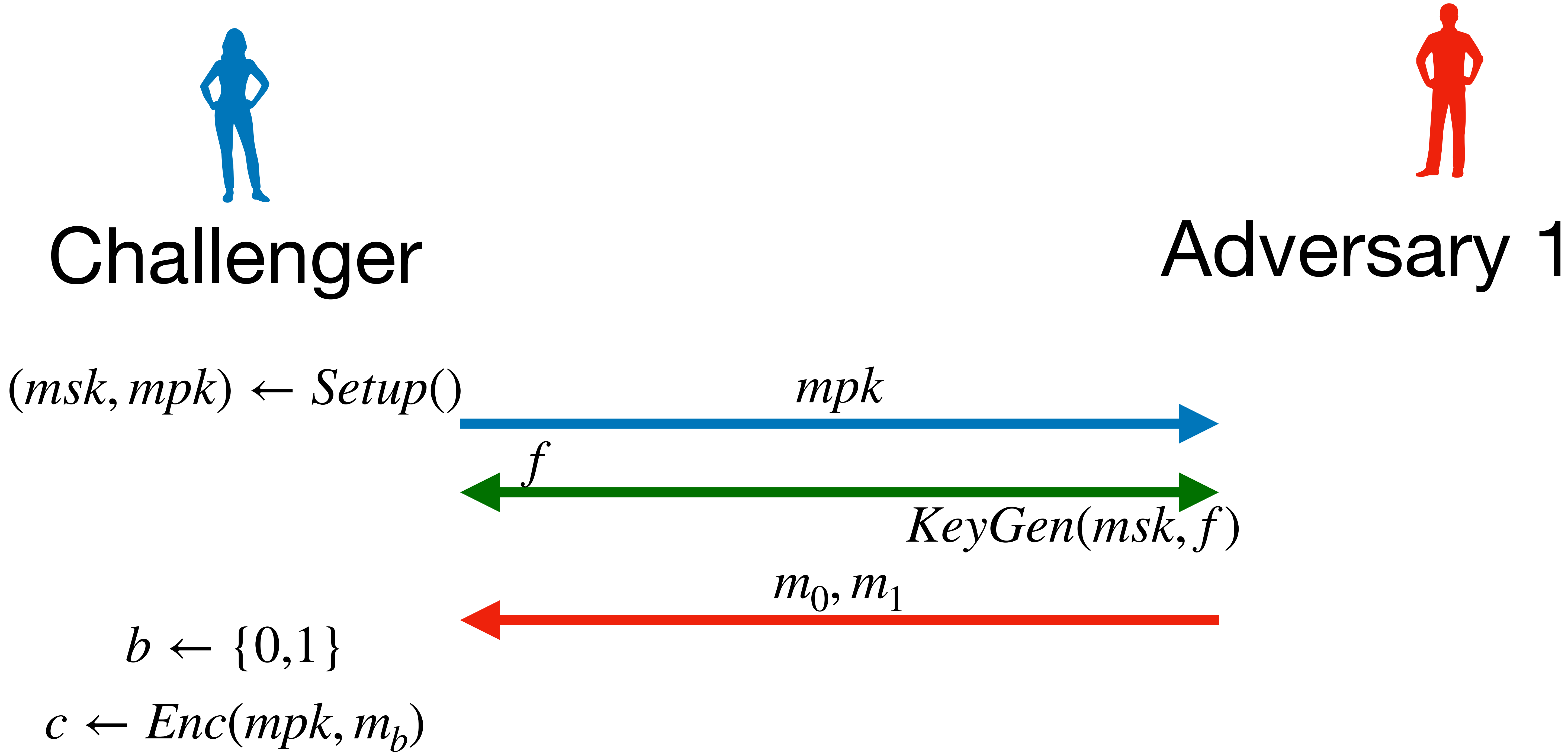

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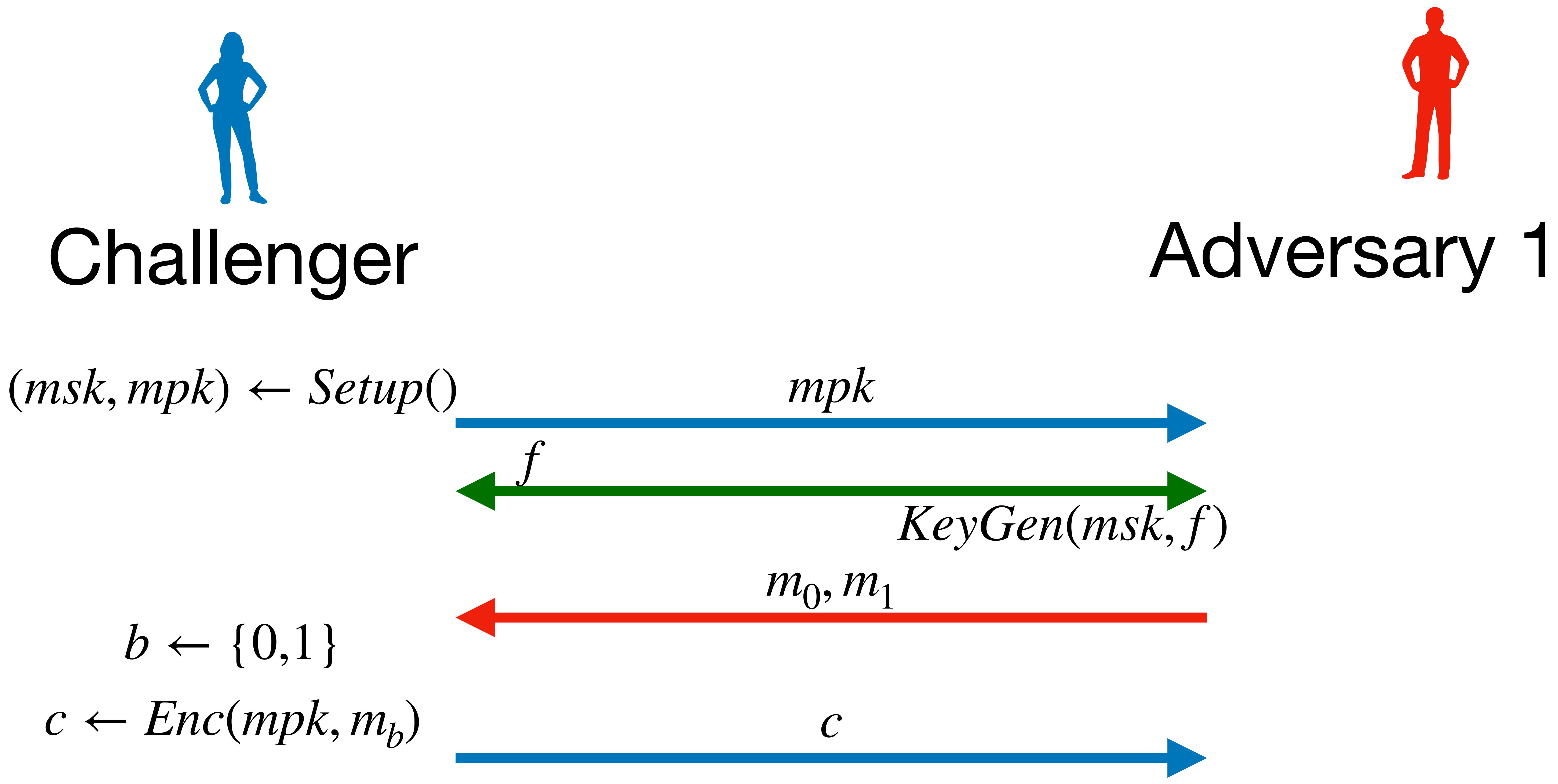

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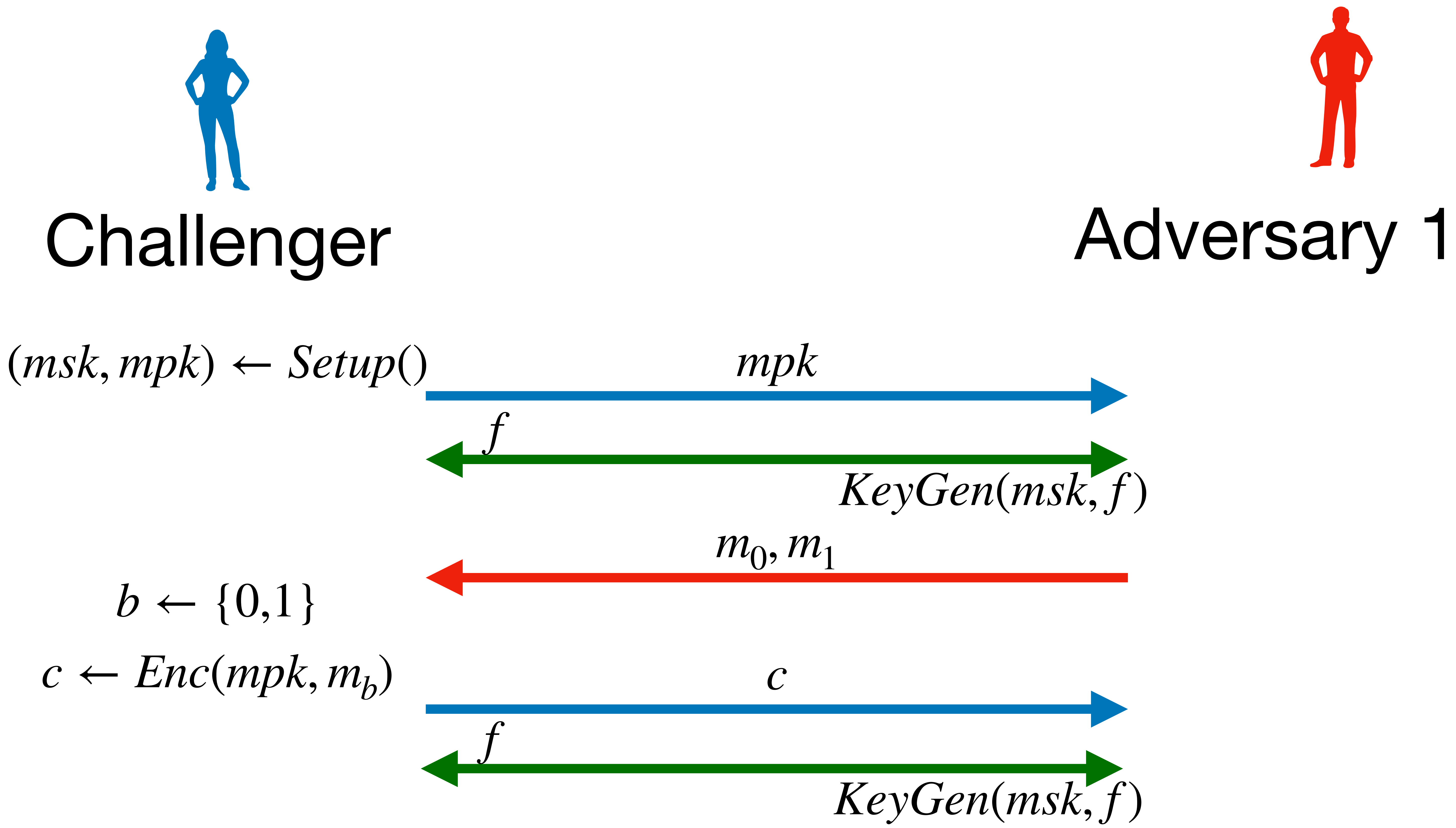

Challenger

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$KeyGen(msk, f)$

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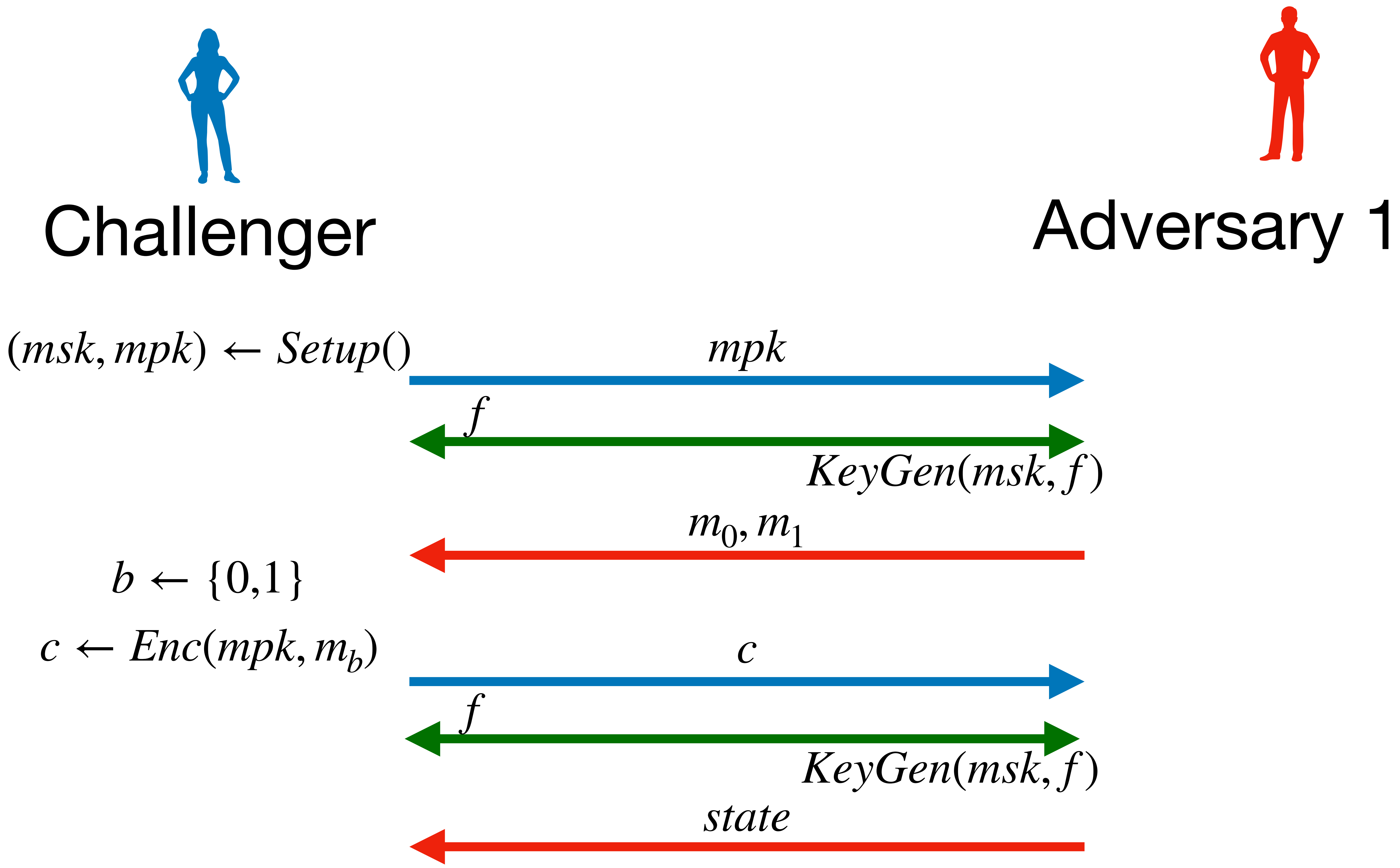

Challenger

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

$c \leftarrow Enc(mpk, m_b)$

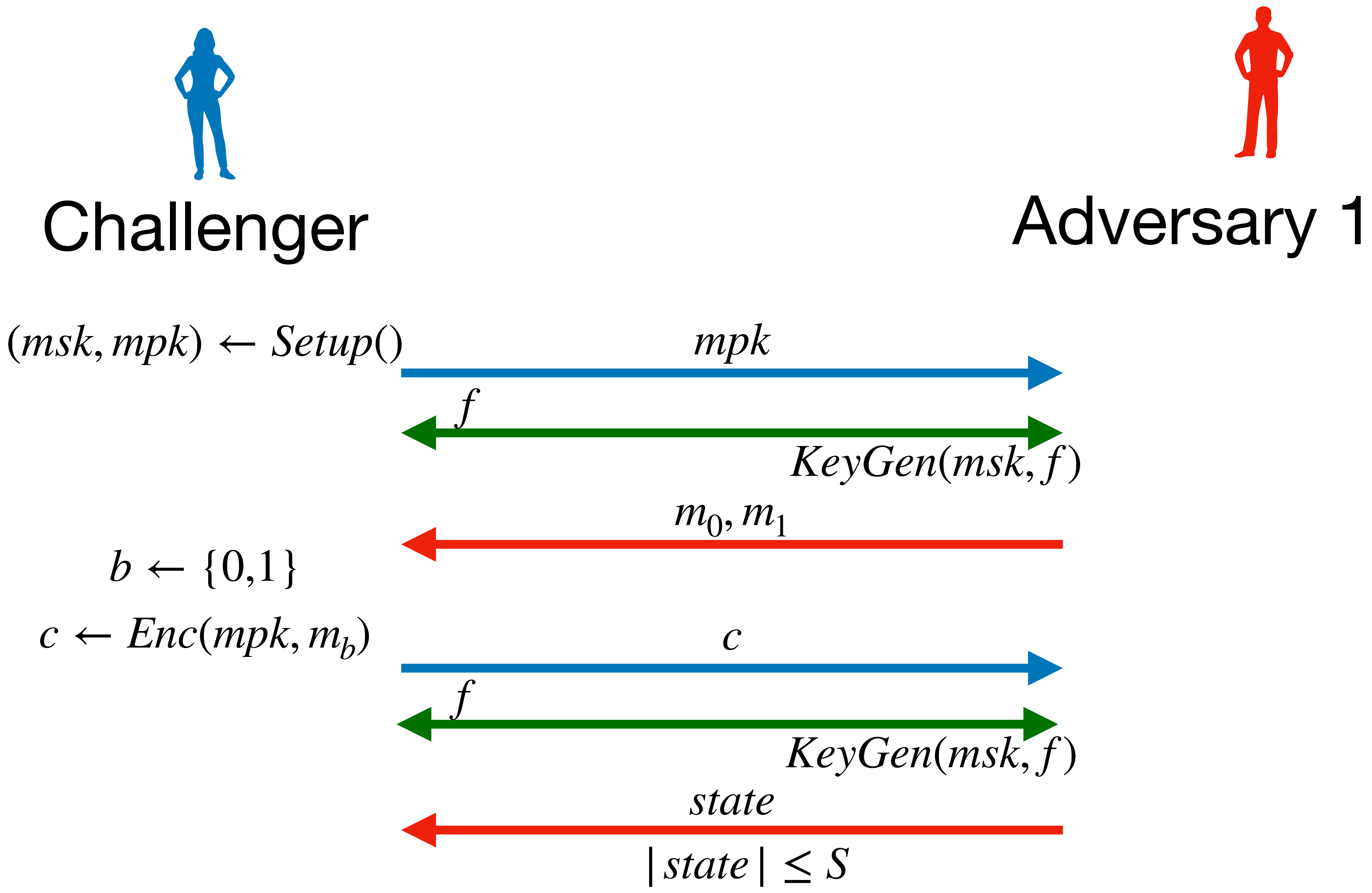
c

f

$KeyGen(msk, f)$

$state$

Semi-Strong Incompressible (FE) Security



Challenger

Adversary 1

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mpk

f

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m_0, m_1

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c

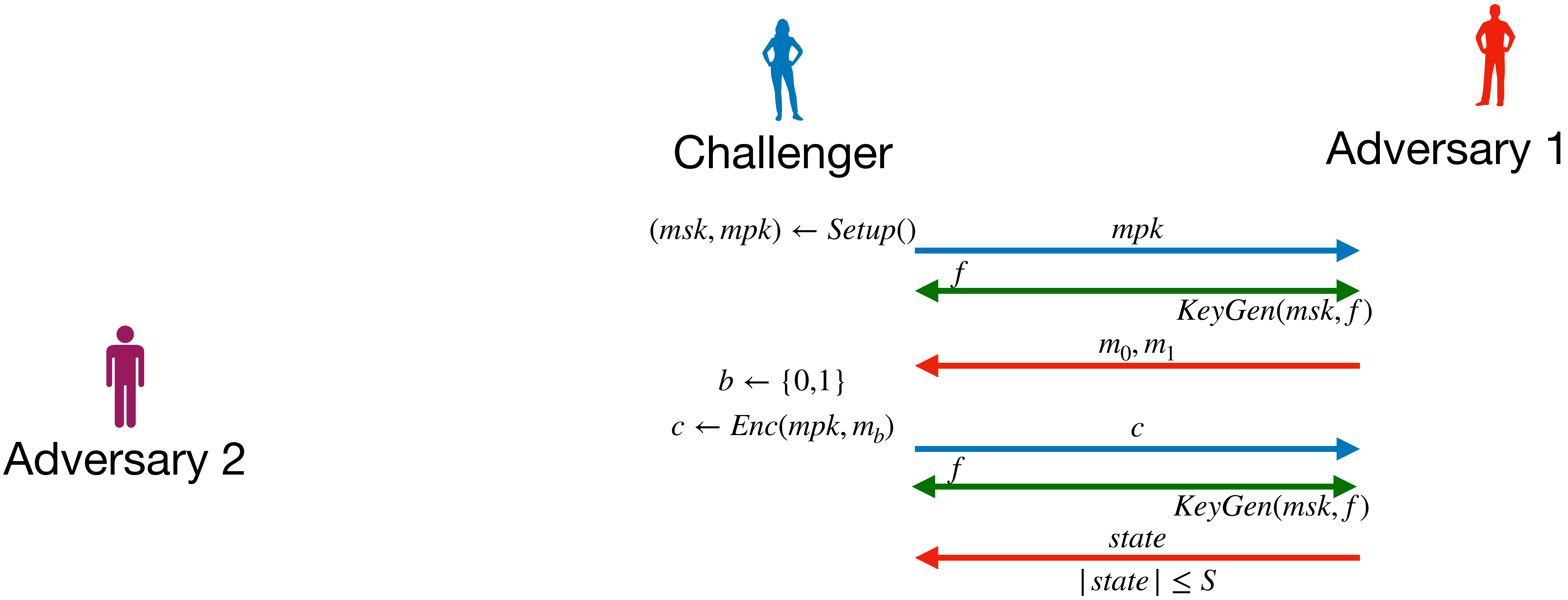
f

$KeyGen(msk, f)$

$state$

$|state| \leq S$

Semi-Strong Incompressible (FE) Security



Challenger

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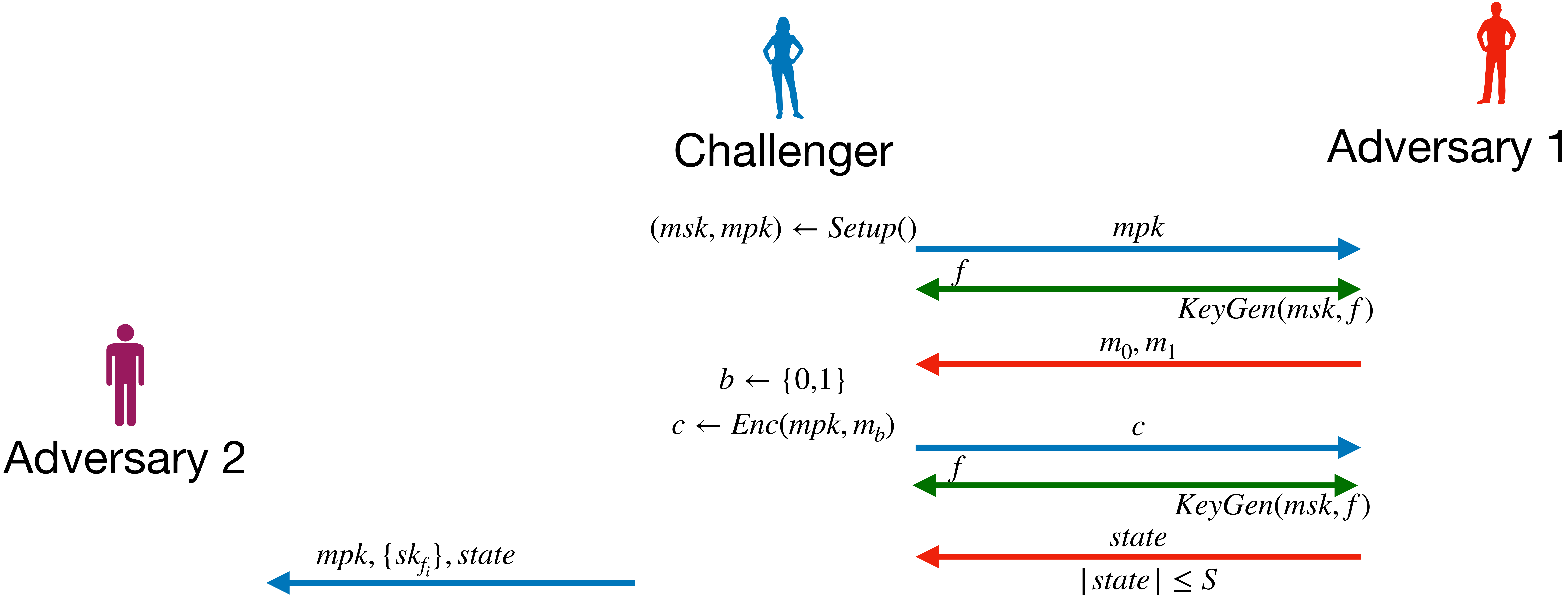


Challenger

Adversary 1

Adversary 2

$(msk, mpk) \leftarrow Setup()$

mpk

f

$KeyGen(msk, f)$

m_0, m_1

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

$c \leftarrow Enc(mpk, m_b)$

c

f

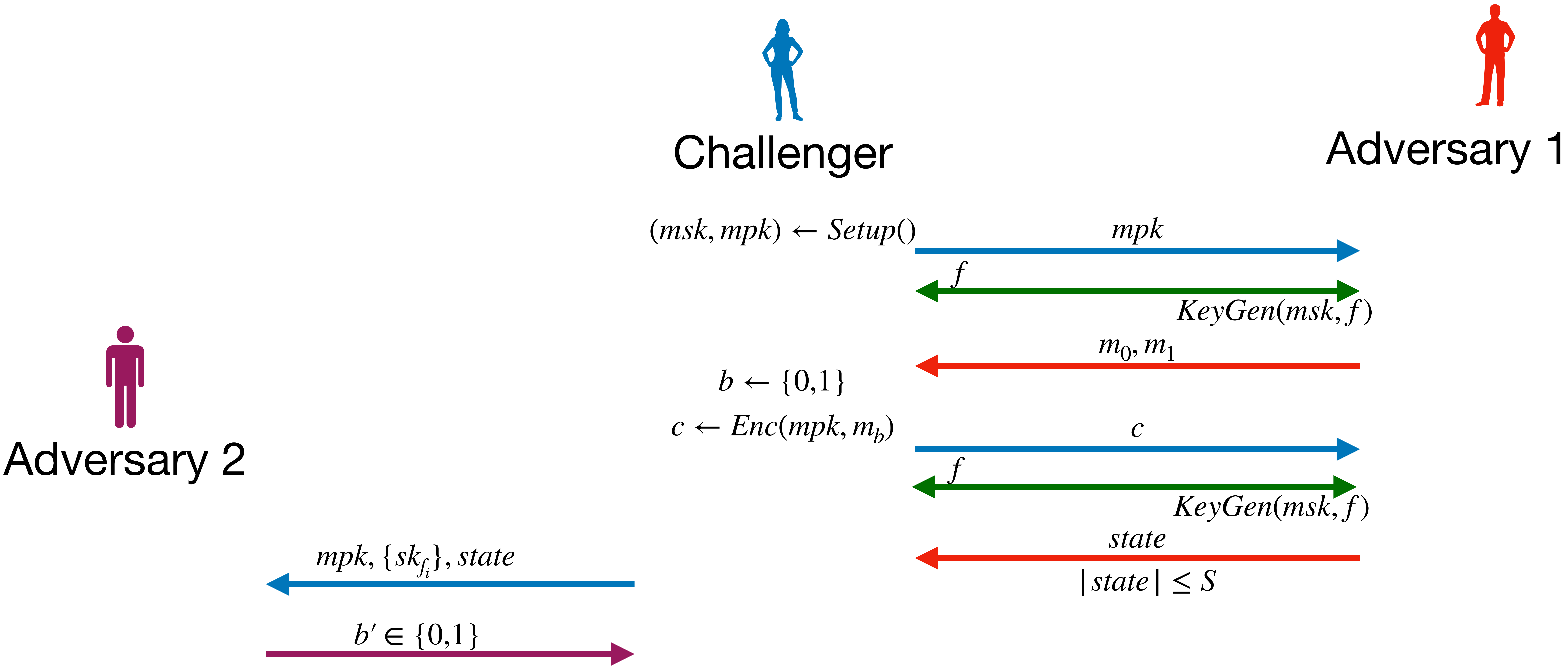
$KeyGen(msk, f)$

$state$

$|state| \leq S$

$mpk, \{sk_{f_i}\}, state$

Semi-Strong Incompressible (FE) Security



Challenger

Adversary 1

$(msk, mpk) \leftarrow Setup()$

mpk

f

$KeyGen(msk, f)$

m_0, m_1

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

$c \leftarrow Enc(mpk, m_b)$

c

f

$KeyGen(msk, f)$

$state$

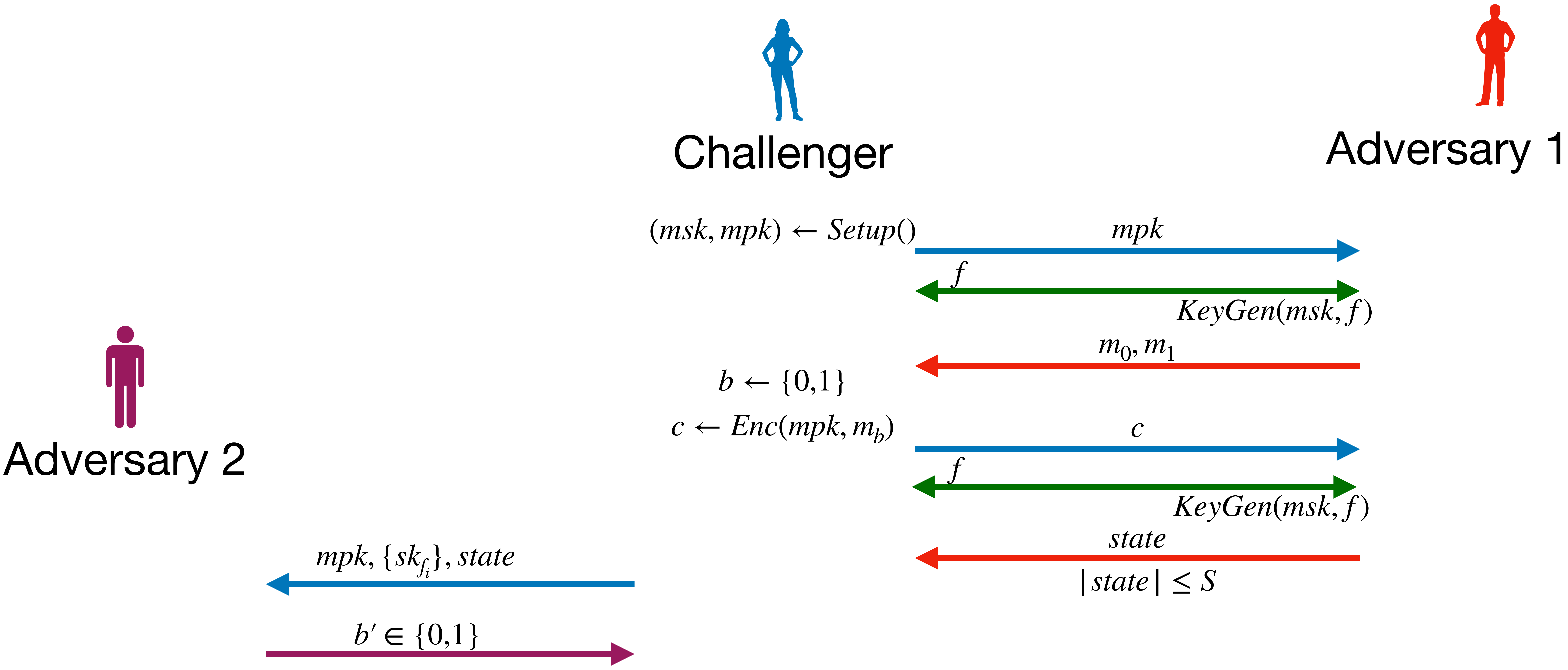
$|state| \leq S$

Adversary 2

$mpk, \{sk_{f_i}\}, state$

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

Semi-Strong Incompressible (FE) Security



Challenger

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f

$KeyGen(msk, f)$

$state$

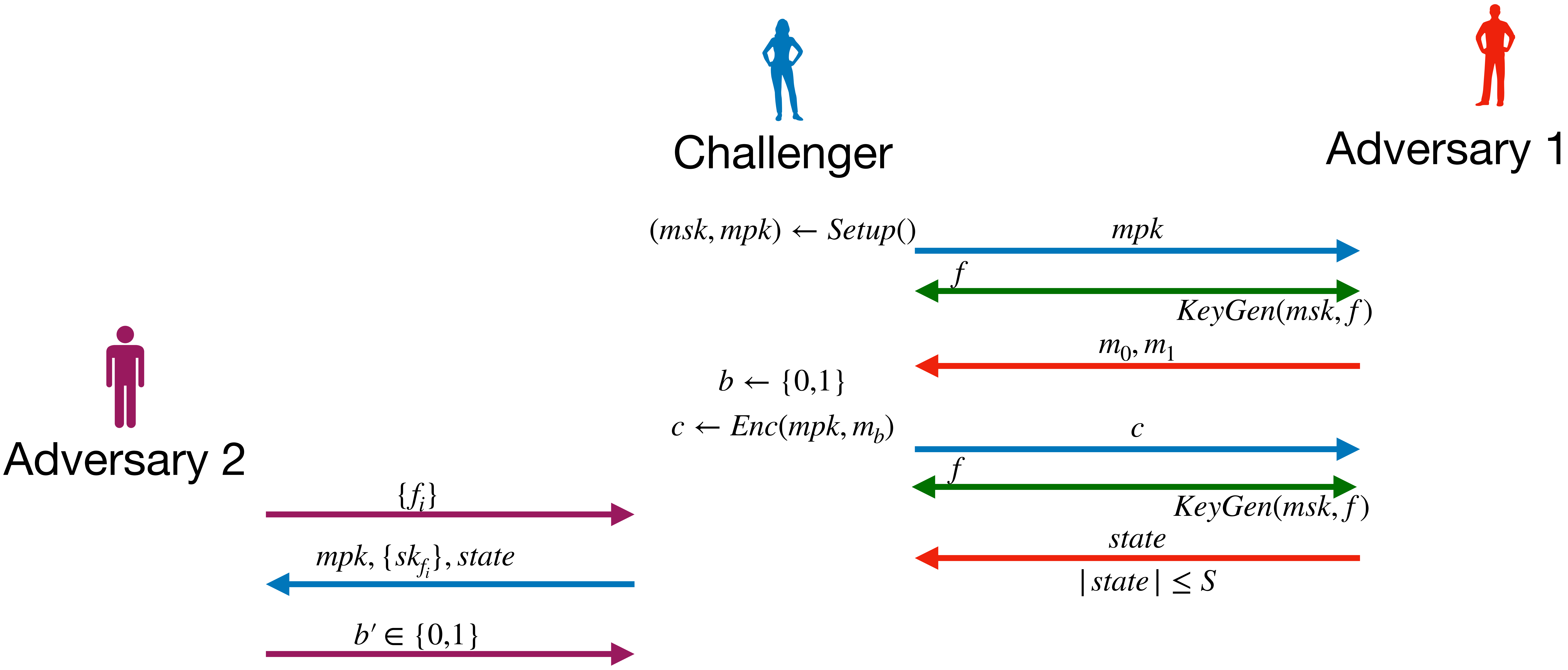
$|state| \leq S$

$mpk, \{sk_{f_i}\}, state$

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

Adversaries wins if $b = b'$

Semi-Strong Incompressible (FE) Security



Challenger

Adversary 1

$(msk, mpk) \leftarrow Setup()$

mpk

f

$KeyGen(msk, f)$

m_0, m_1

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

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c

f

$KeyGen(msk, f)$

$state$

$|state| \leq S$

Adversary 2

$\{f_i\}$

$mpk, \{sk_{f_i}\}, state$

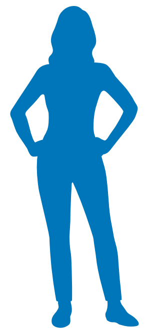
$b' \in \{0,1\}$

Adversaries wins if $b = b'$

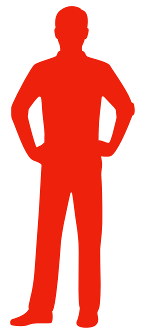
Regular Incompressible (FE) Security

Regular Incompressible (FE) Security

Regular Incompressible (FE) Security

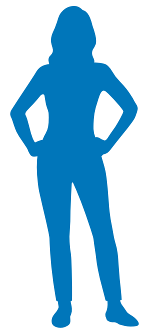


Challenger



Adversary 1

Regular Incompressible (FE) Security



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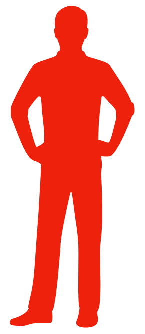
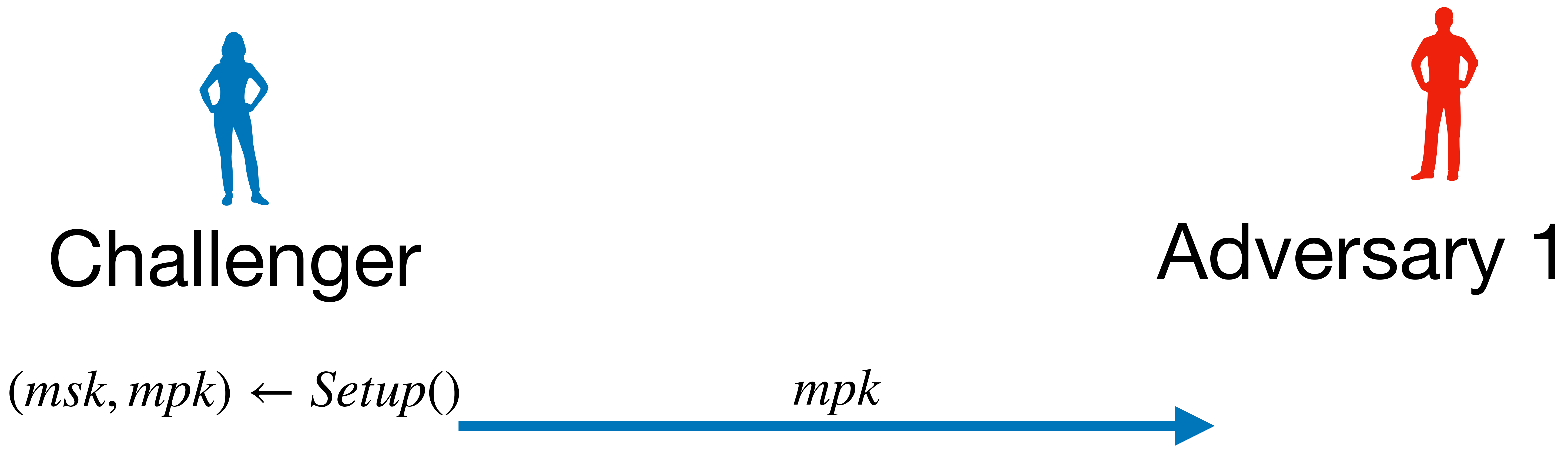


Adversary 1

$$(msk, mpk) \leftarrow Setup()$$

Regular Incompressible (FE) Security

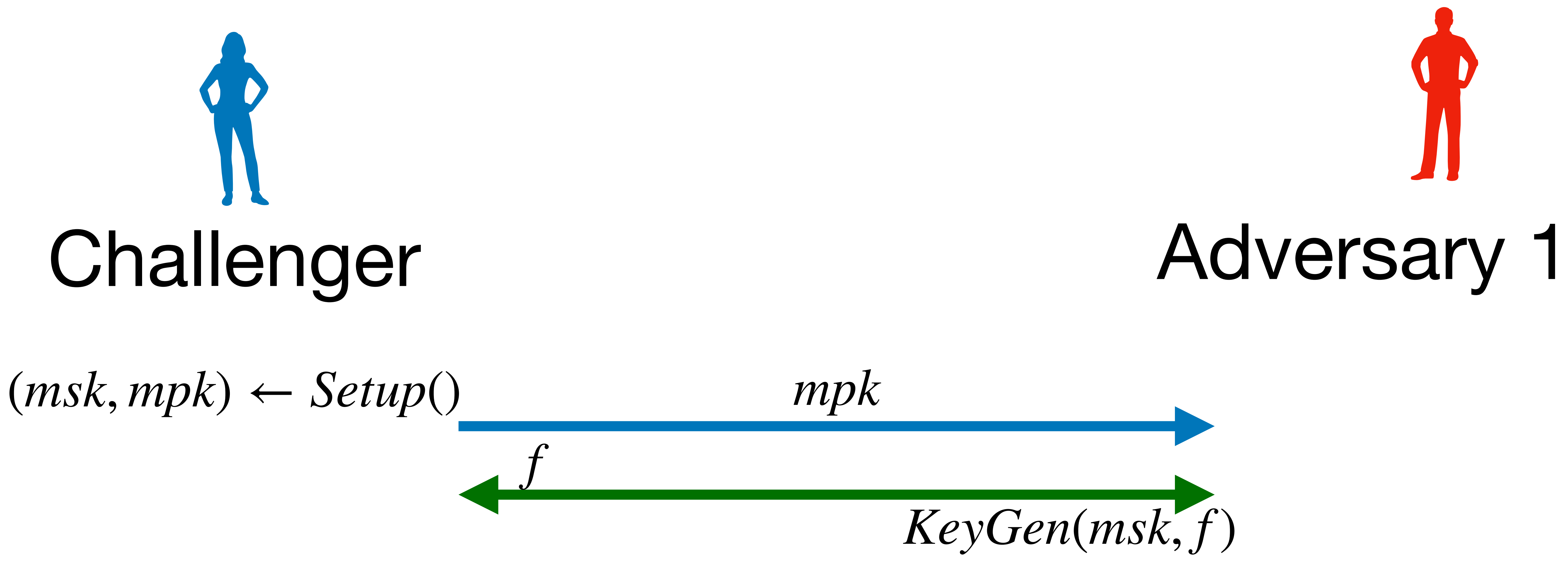


Challenger

Adversary 1

$(msk, mpk) \leftarrow Setup()$ $\xrightarrow{mpk}$

Regular Incompressible (FE) Security



Challenger

Adversary 1

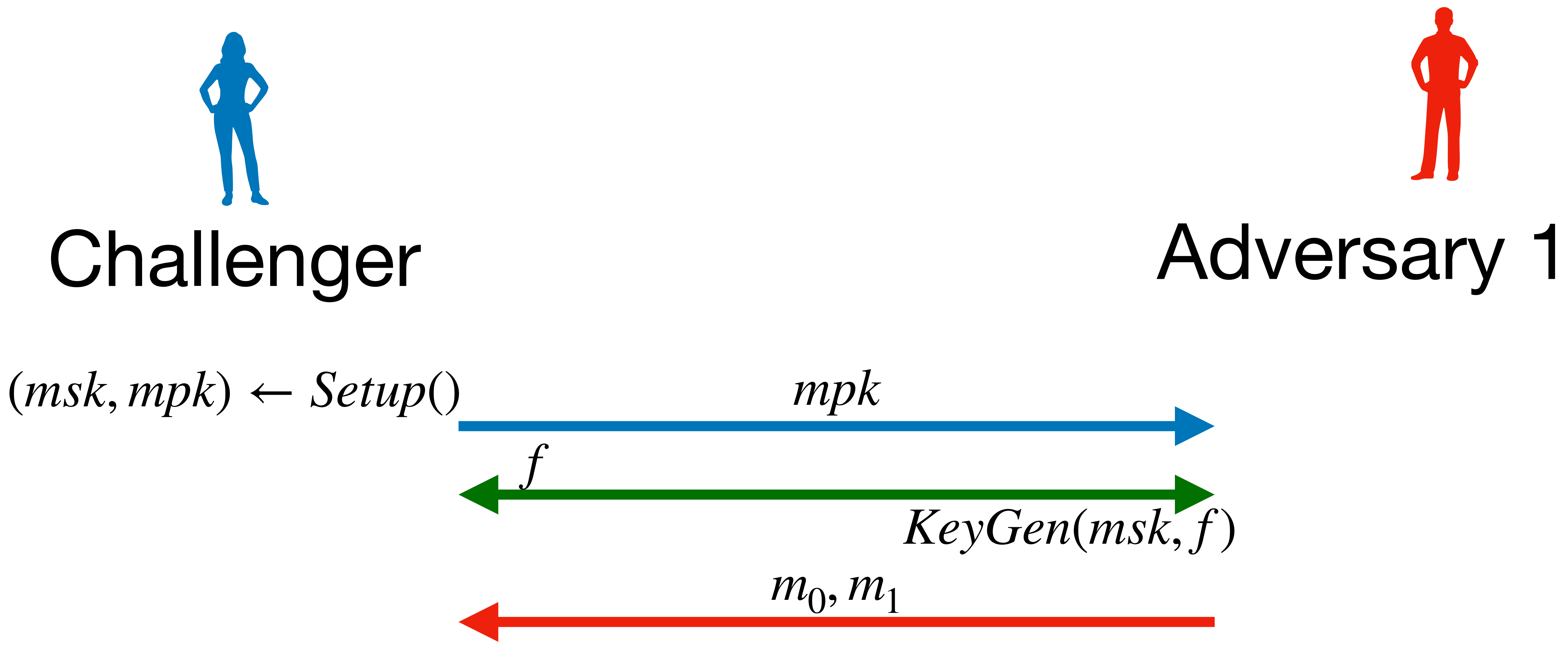
$(msk, mpk) \leftarrow Setup()$

mpk

f

$KeyGen(msk, f)$

Regular Incompressible (FE) Security



Challenger

Adversary 1

$(msk, mpk) \leftarrow Setup()$

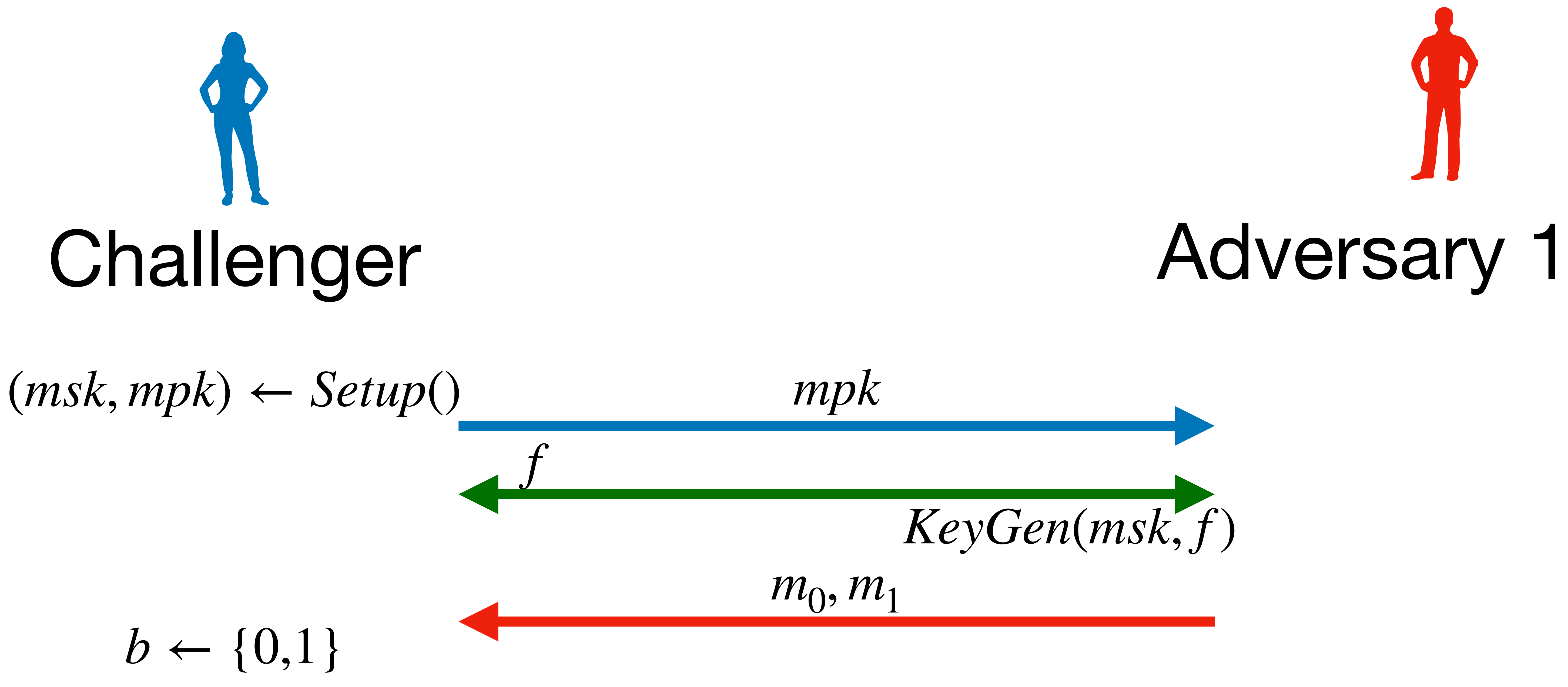
mpk

f

$KeyGen(msk, f)$

m_0, m_1

Regular Incompressible (FE) Security



Challenger

Adversary 1

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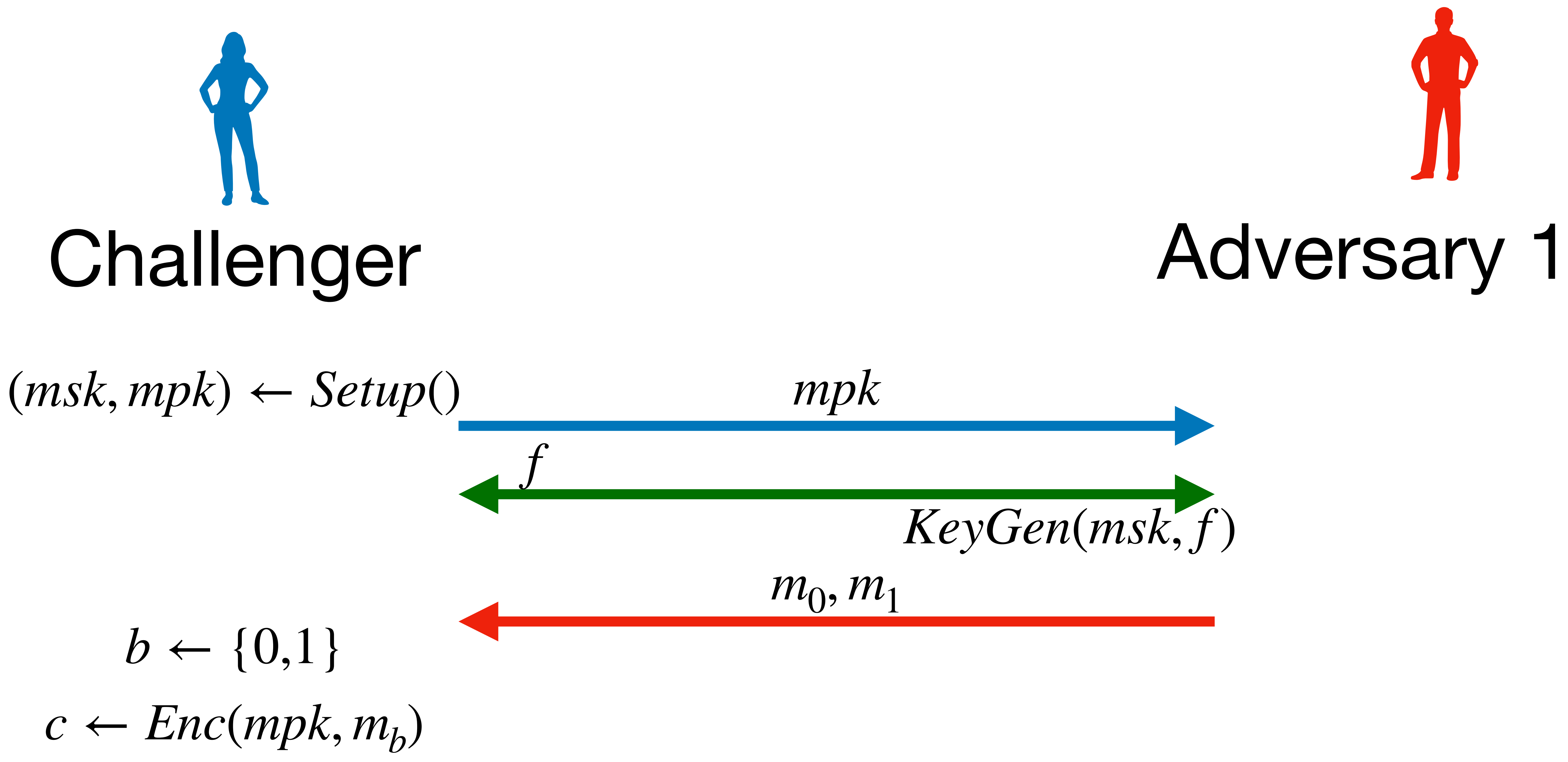
$KeyGen(msk, f)$

m_0, m_1

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

Regular Incompressible (FE) Security



Challenger

Adversary 1

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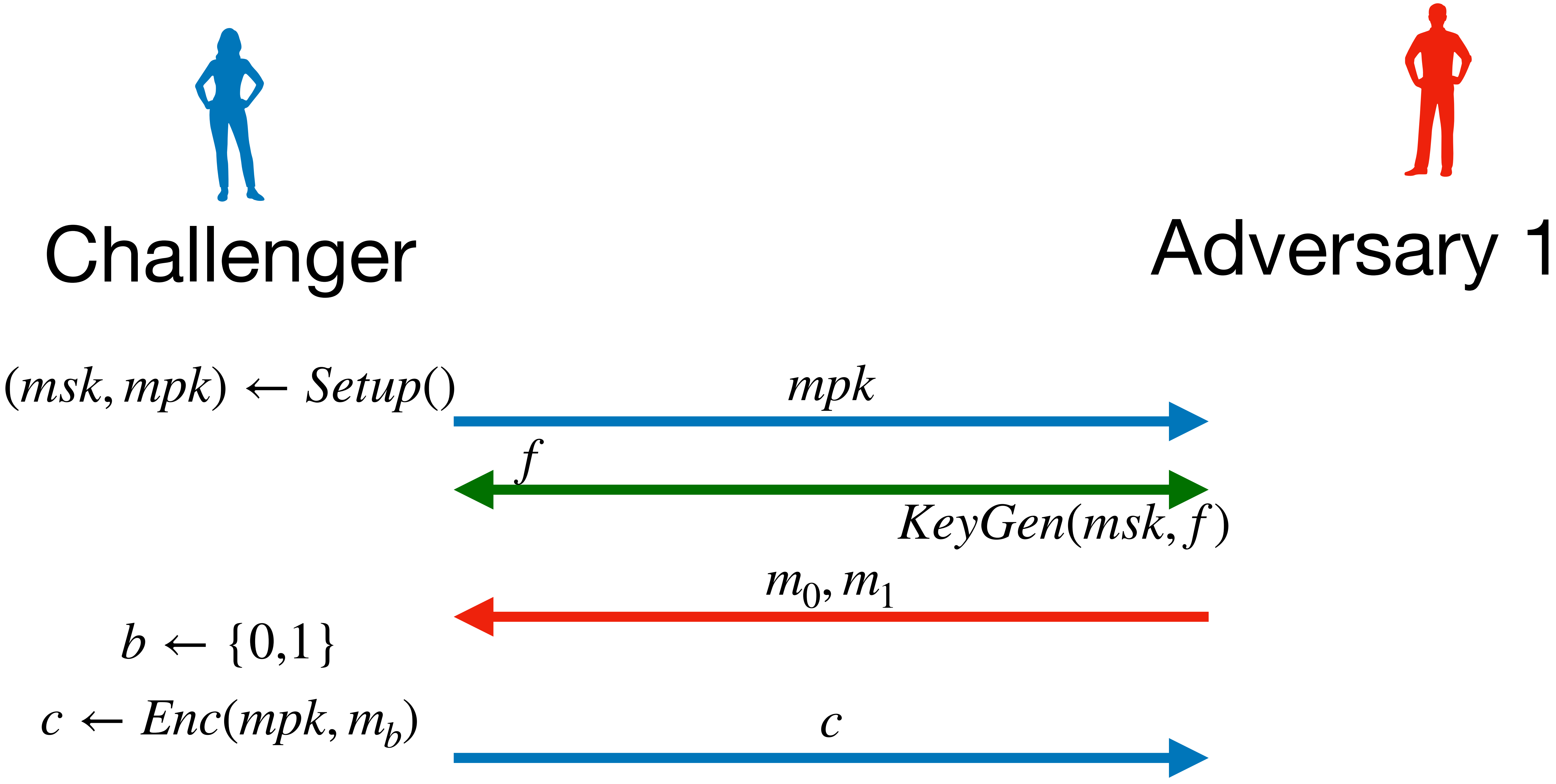
Regular Incompressible (FE) Security



Challenger

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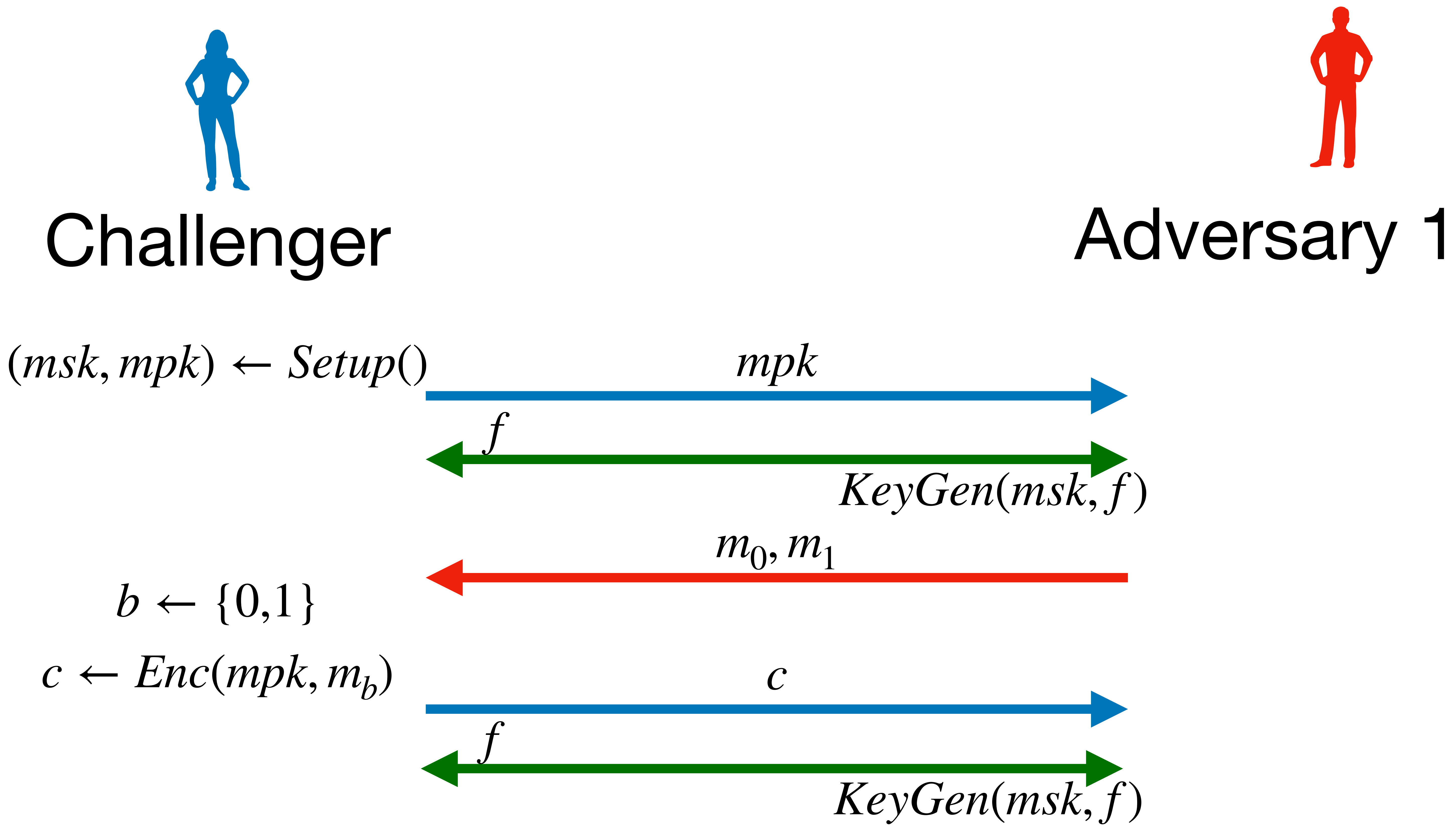
c

Regular Incompressible (FE) Security



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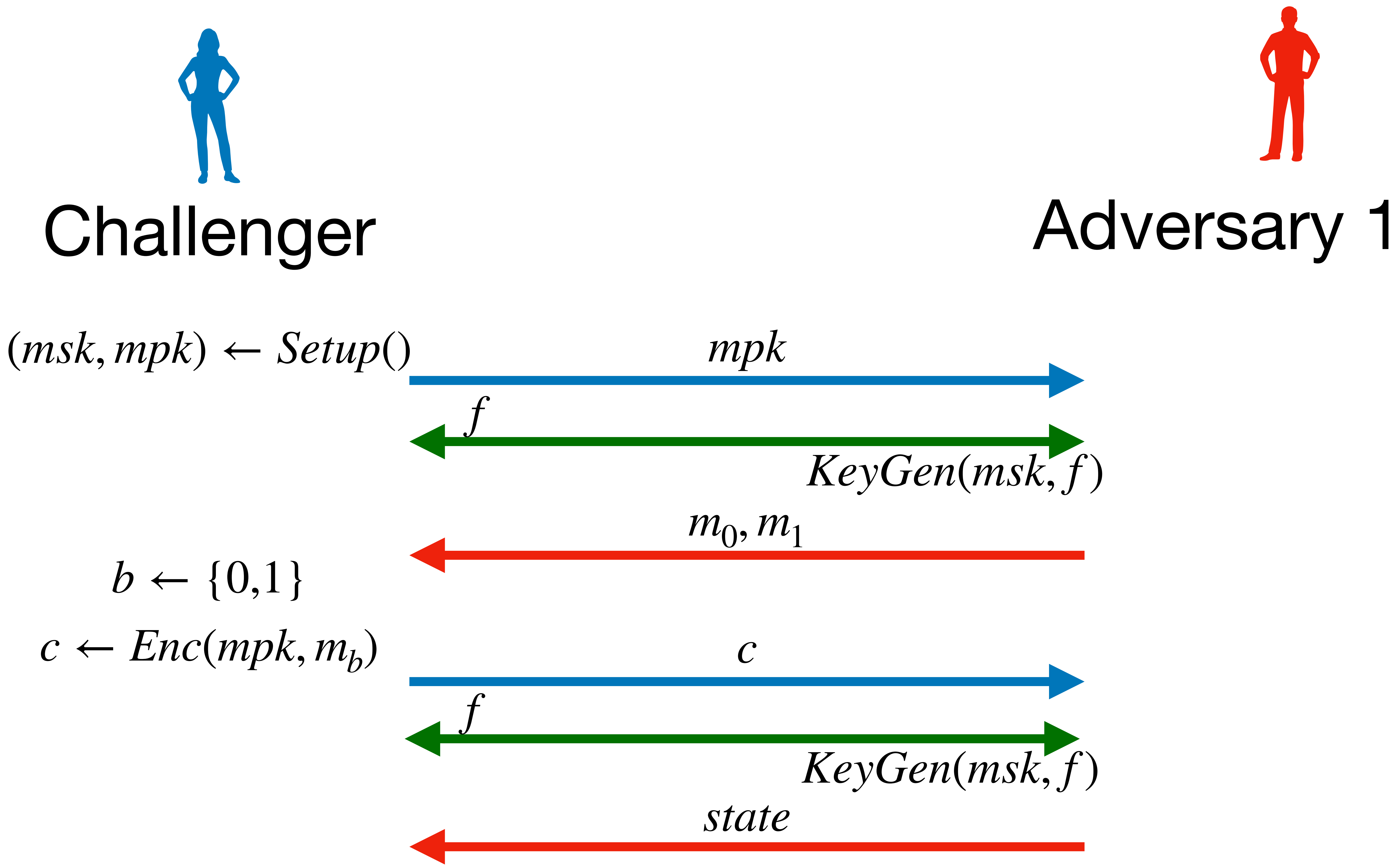

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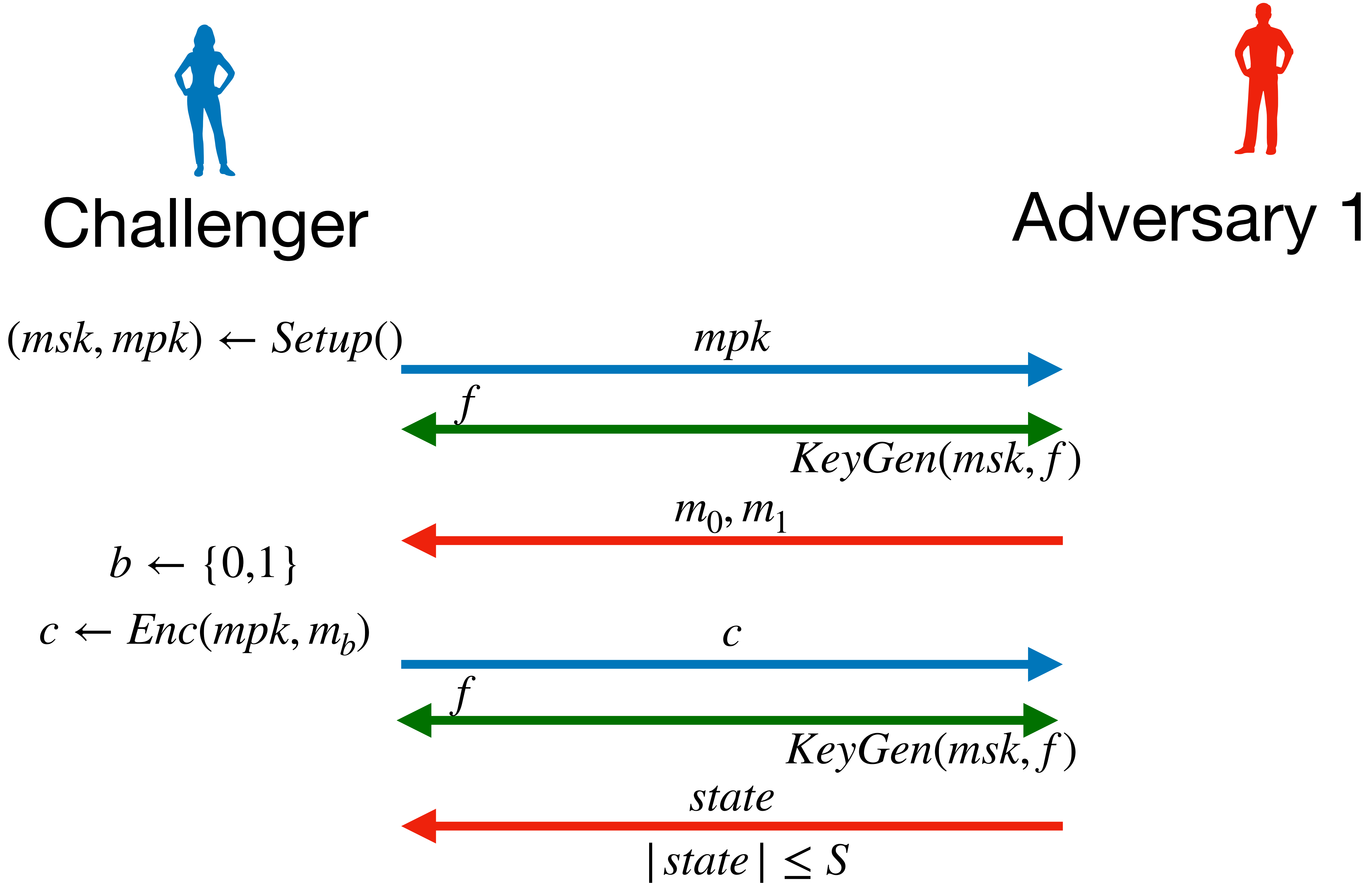
$KeyGen(msk, f)$

$state$

Regular Incompressible (FE) Security



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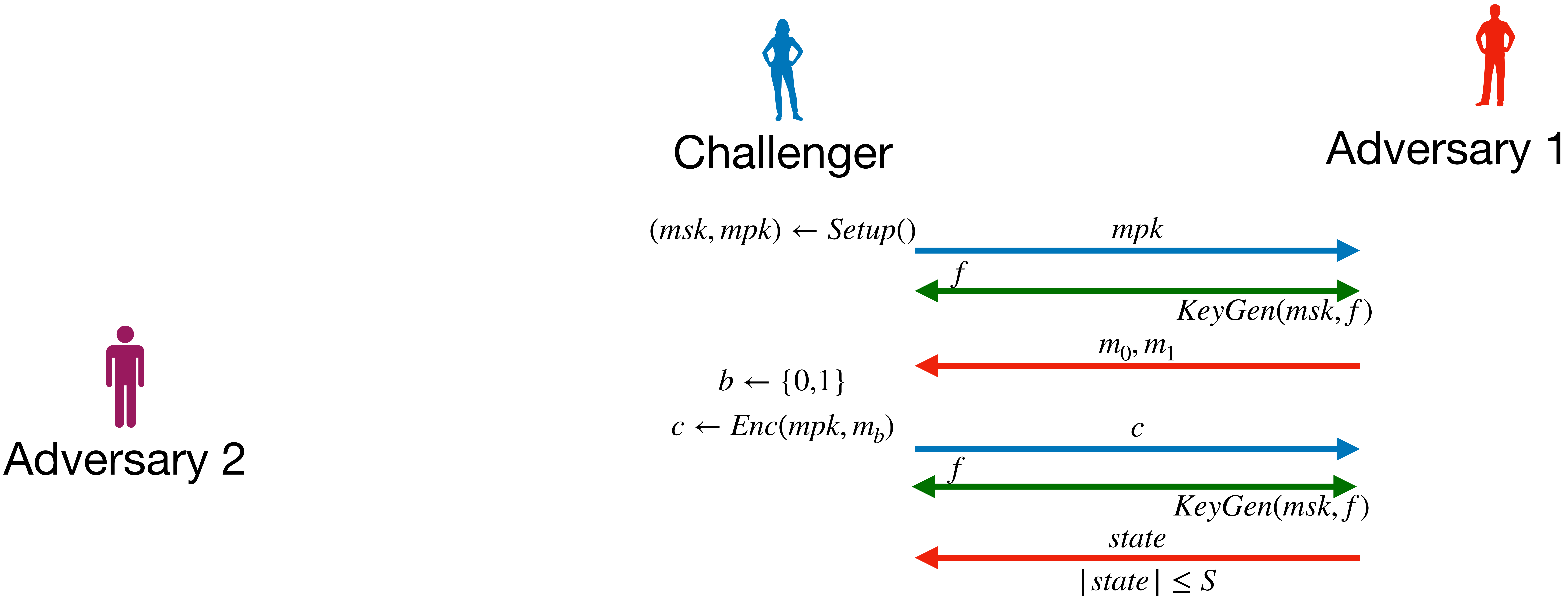

Challenger

Adversary 1

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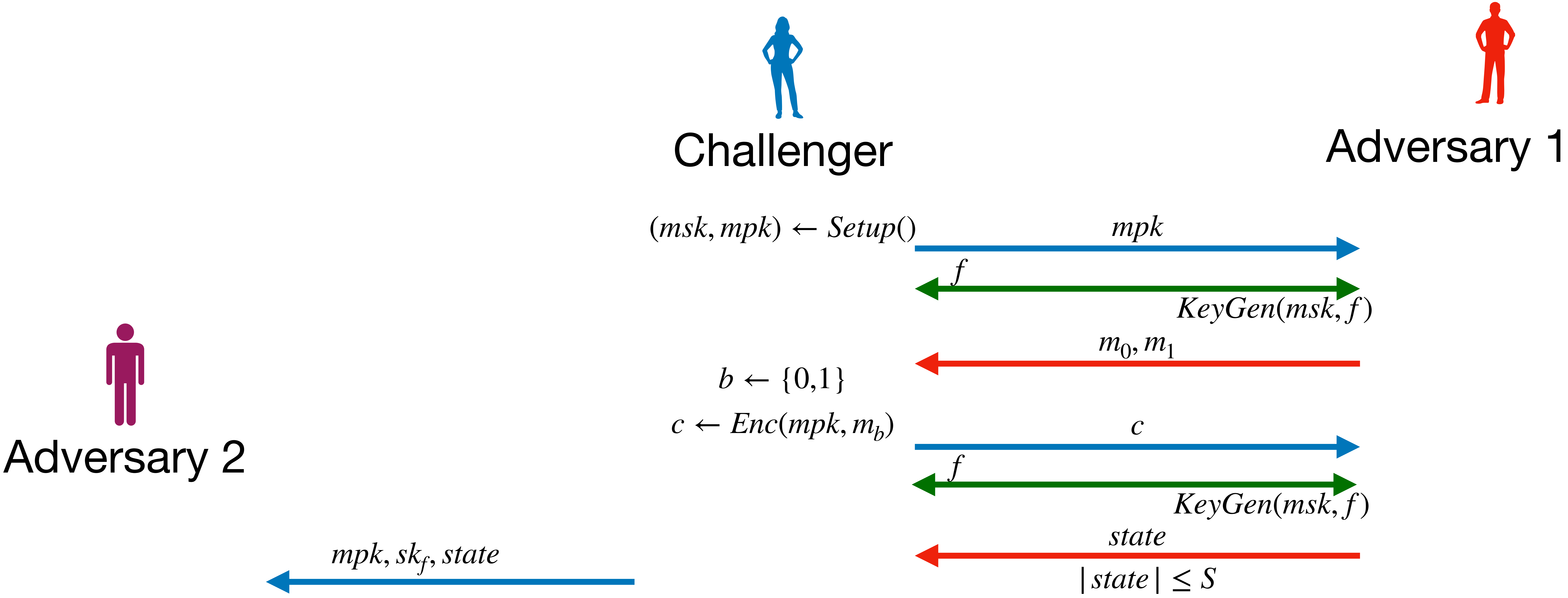

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mpk

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$KeyGen(msk, f)$

$state$

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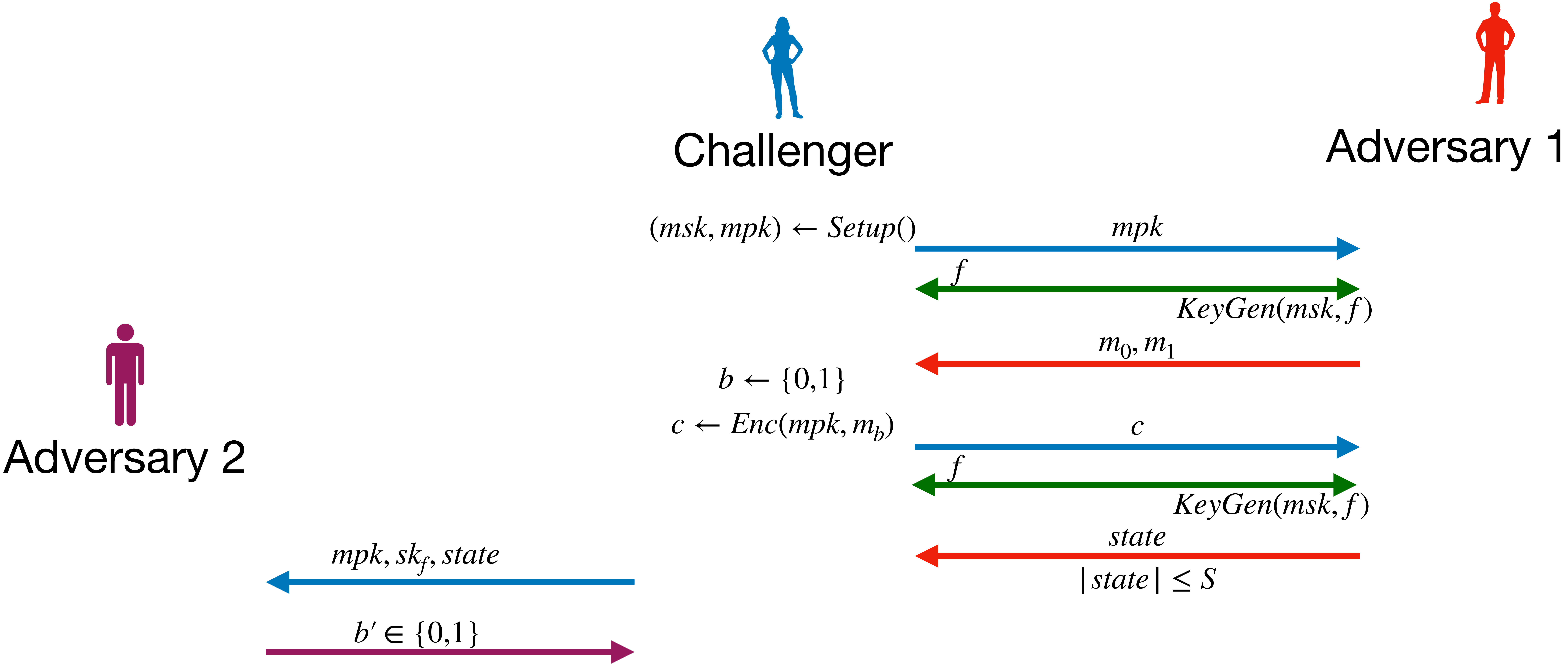
$mpk, sk_f, state$

Regular Incompressible (FE) Security



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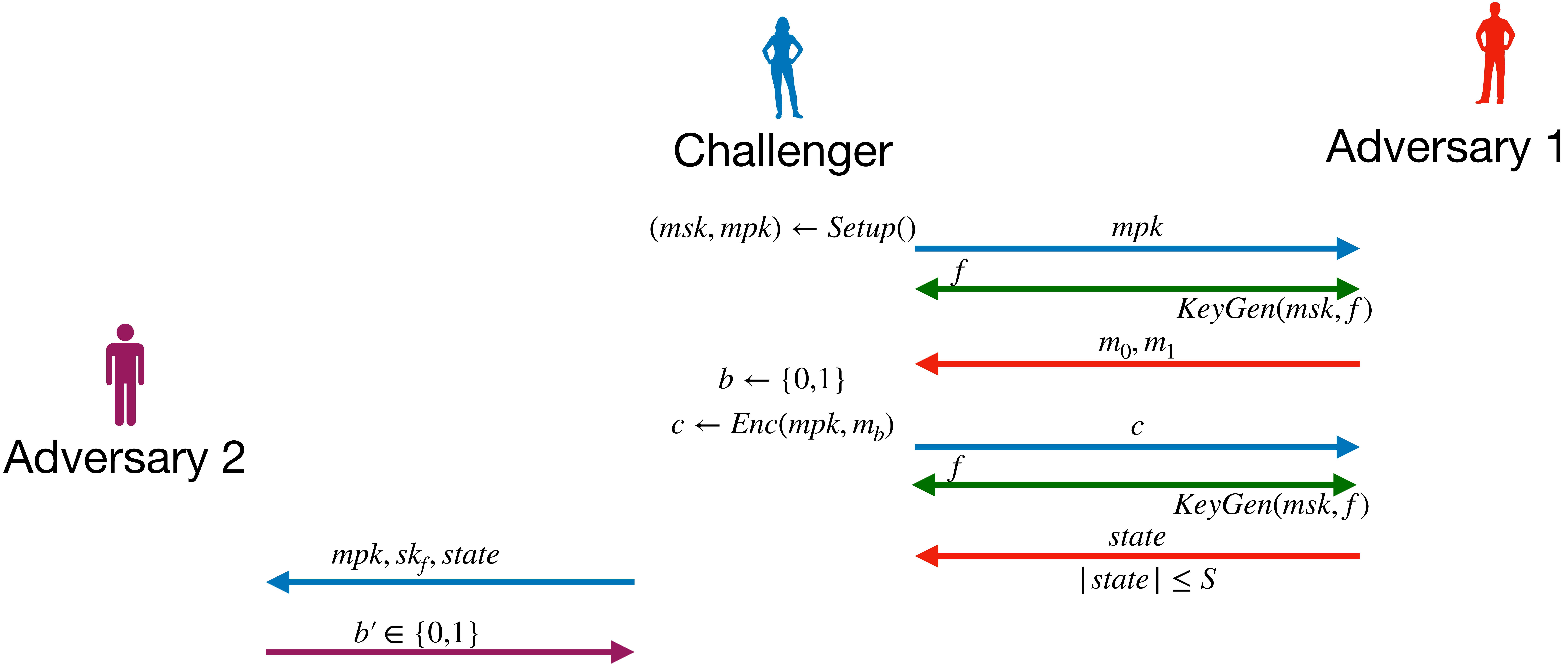

Challenger

Adversary 1

Adversary 2

$(msk, mpk) \leftarrow Setup()$ $\xrightarrow{mpk}$

f / $KeyGen(msk, f)$

m_0, m_1

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

$c \leftarrow Enc(mpk, m_b)$ $\xrightarrow{c}$

f / $KeyGen(msk, f)$

$state$

$|state| \leq S$

$mpk, sk_f, state$

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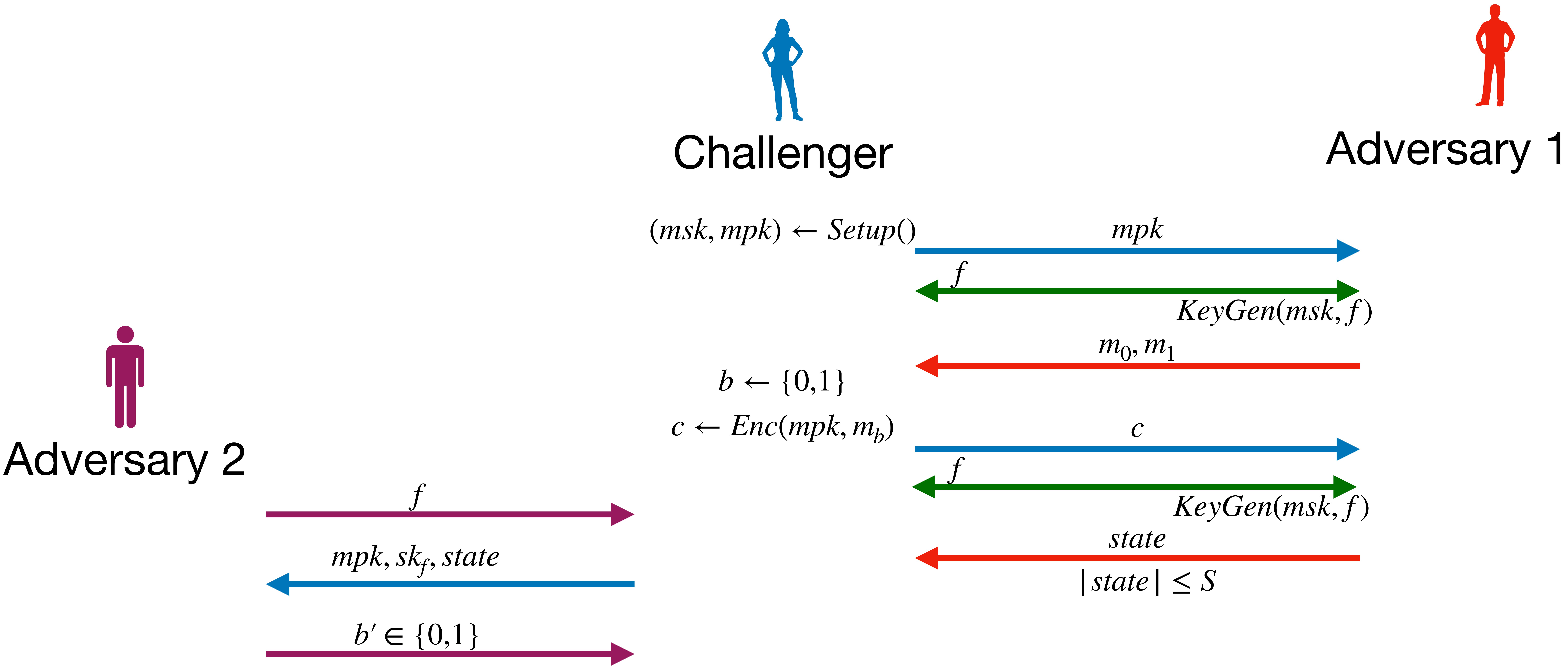
Adversaries wins if $b = b'$

Regular Incompressible (FE) Security



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$|state| \leq S$

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$mpk, sk_f, state$

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Our Results

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- Gave an incompressible FE scheme where second adversary can ask for polynomially many distinguishing keys.

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- Construction is based on “Trojan Horse” technique.

Conclusion

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- Focussed on constructions for incompressible SKE and PKE.
- Looked at incompressible IBE & FE security definition.
- Open problem : Is it possible to define incompressible version of other primitive and give a construction?

Thank You

Bounded Storage Model [Mau92]

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- Key agreement [CM97,GZ19,DQW21], Commitment [DLN15,GZ19], etc.

Standard Security (CCA)

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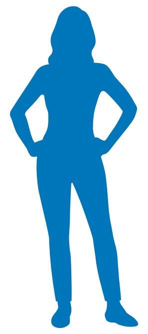
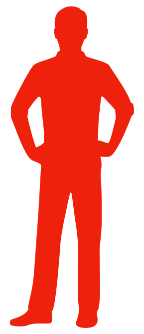
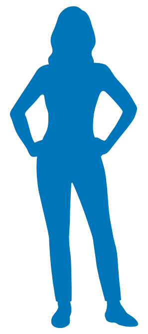


Challenger



Adversary

Standard Security (CCA)



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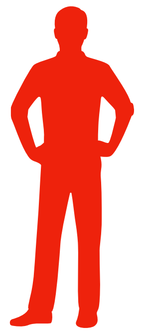
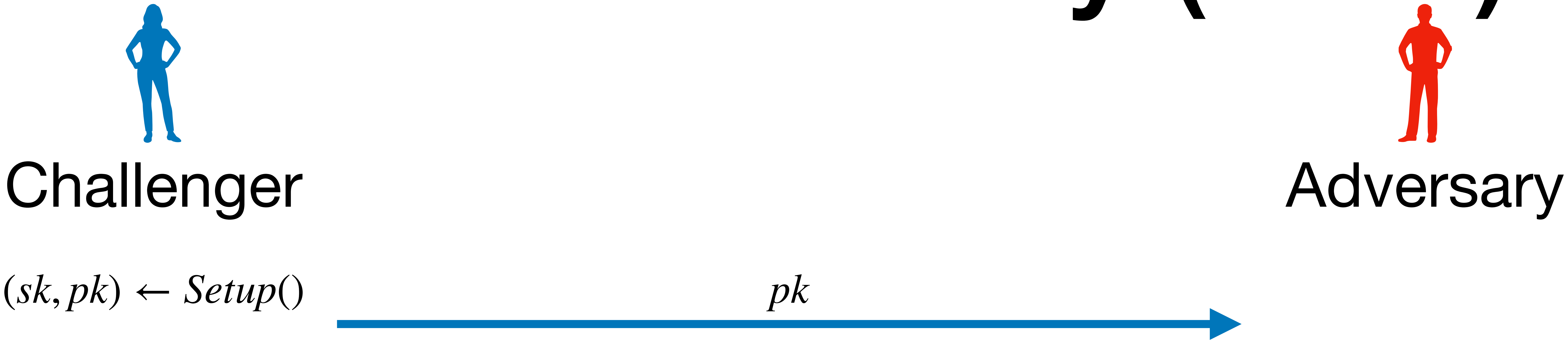


Adversary

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

Standard Security (CCA)



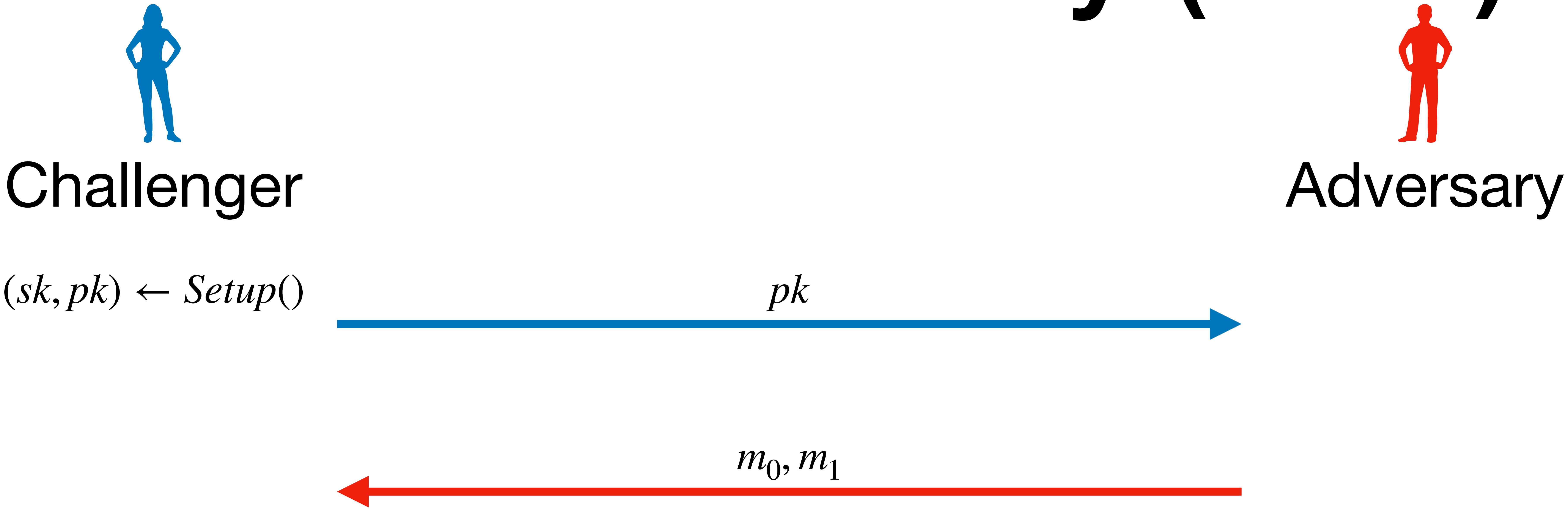
Challenger

Adversary

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

pk

Standard Security (CCA)



Challenger

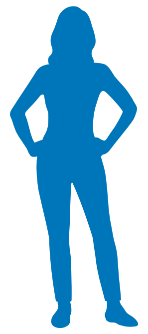
Adversary

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

pk

m_0, m_1

Standard Security (CCA)



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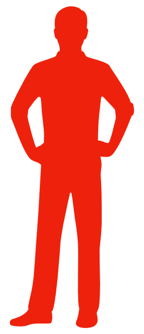
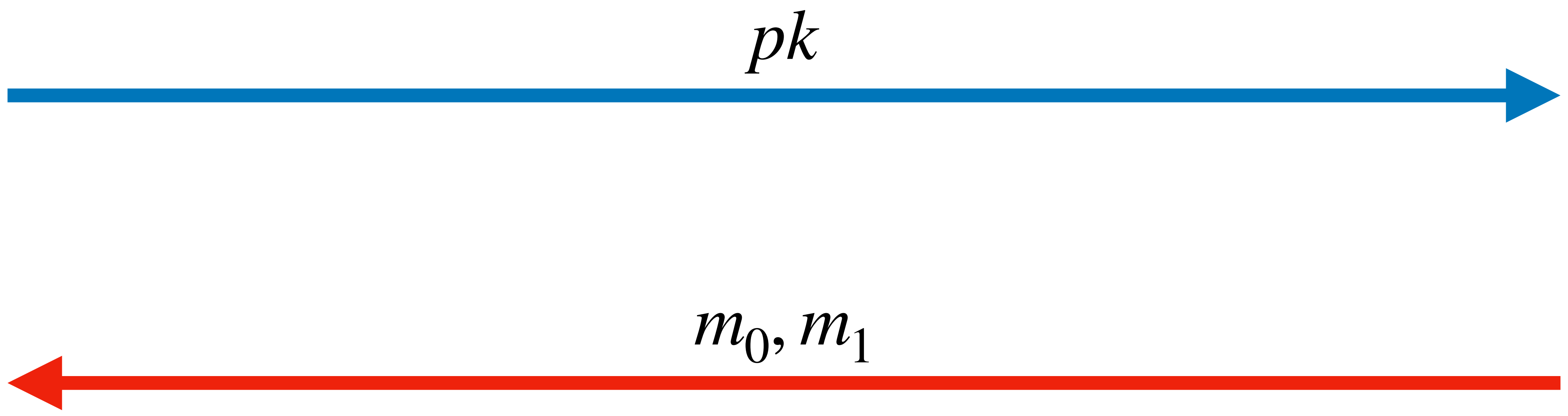


Adversary



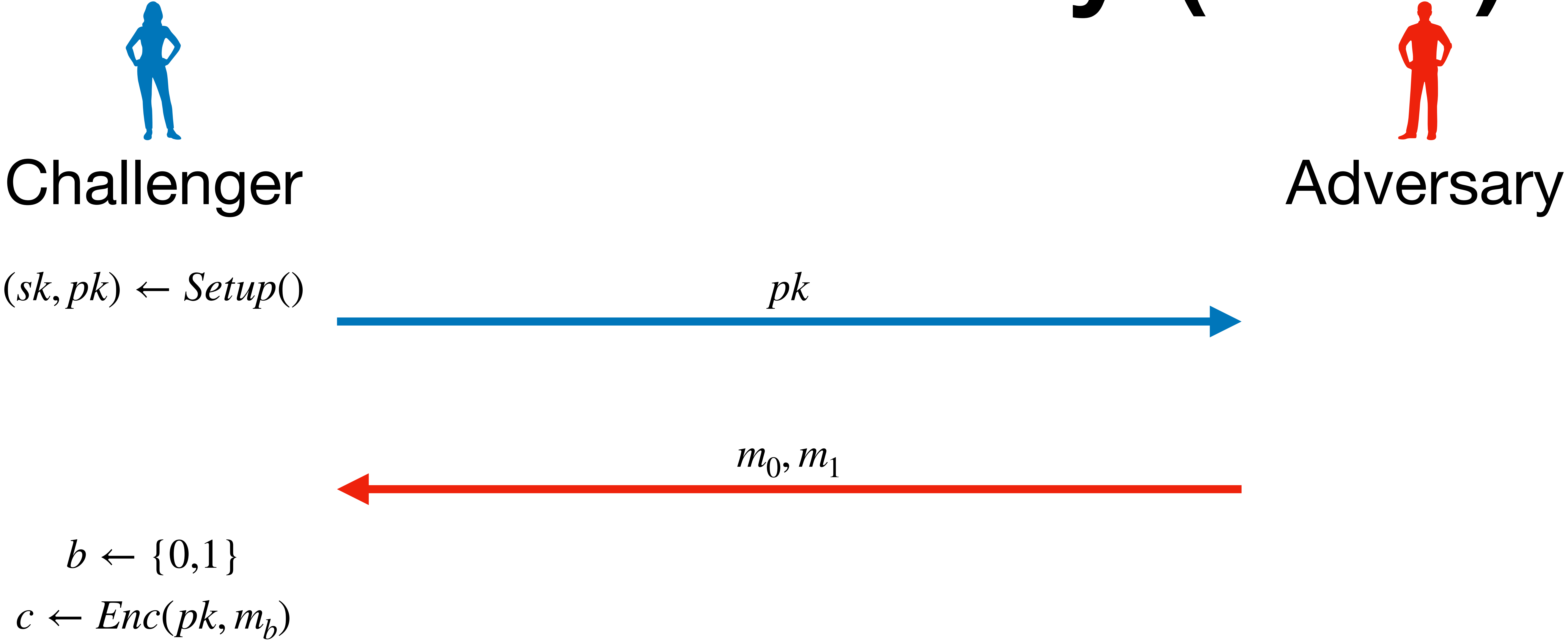
$(sk, pk) \leftarrow Setup()$

pk

m_0, m_1

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

Standard Security (CCA)



Challenger

Adversary

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

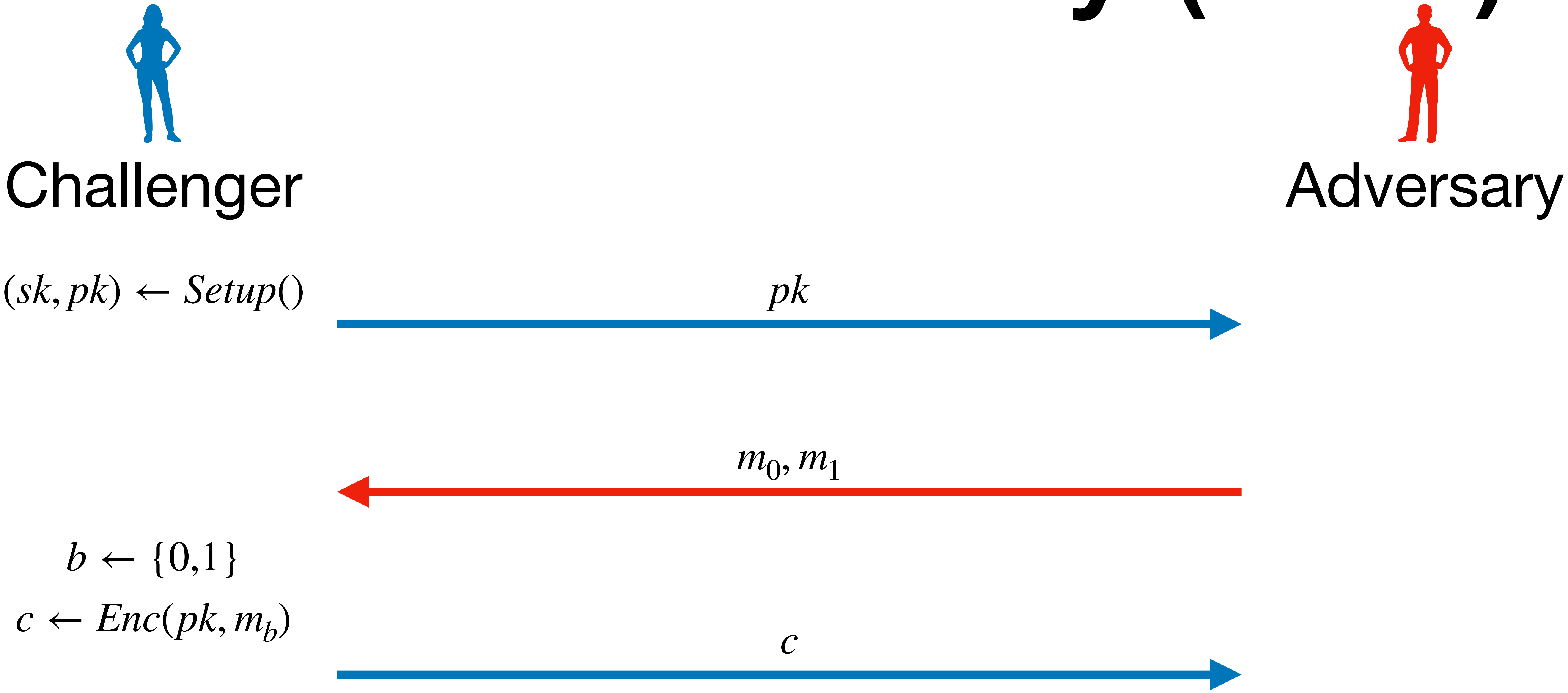
$\xrightarrow{pk}$

$\xleftarrow{m_0, m_1}$

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

$c \leftarrow Enc(pk, m_b)$

Standard Security (CCA)



Challenger

Adversary

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

pk

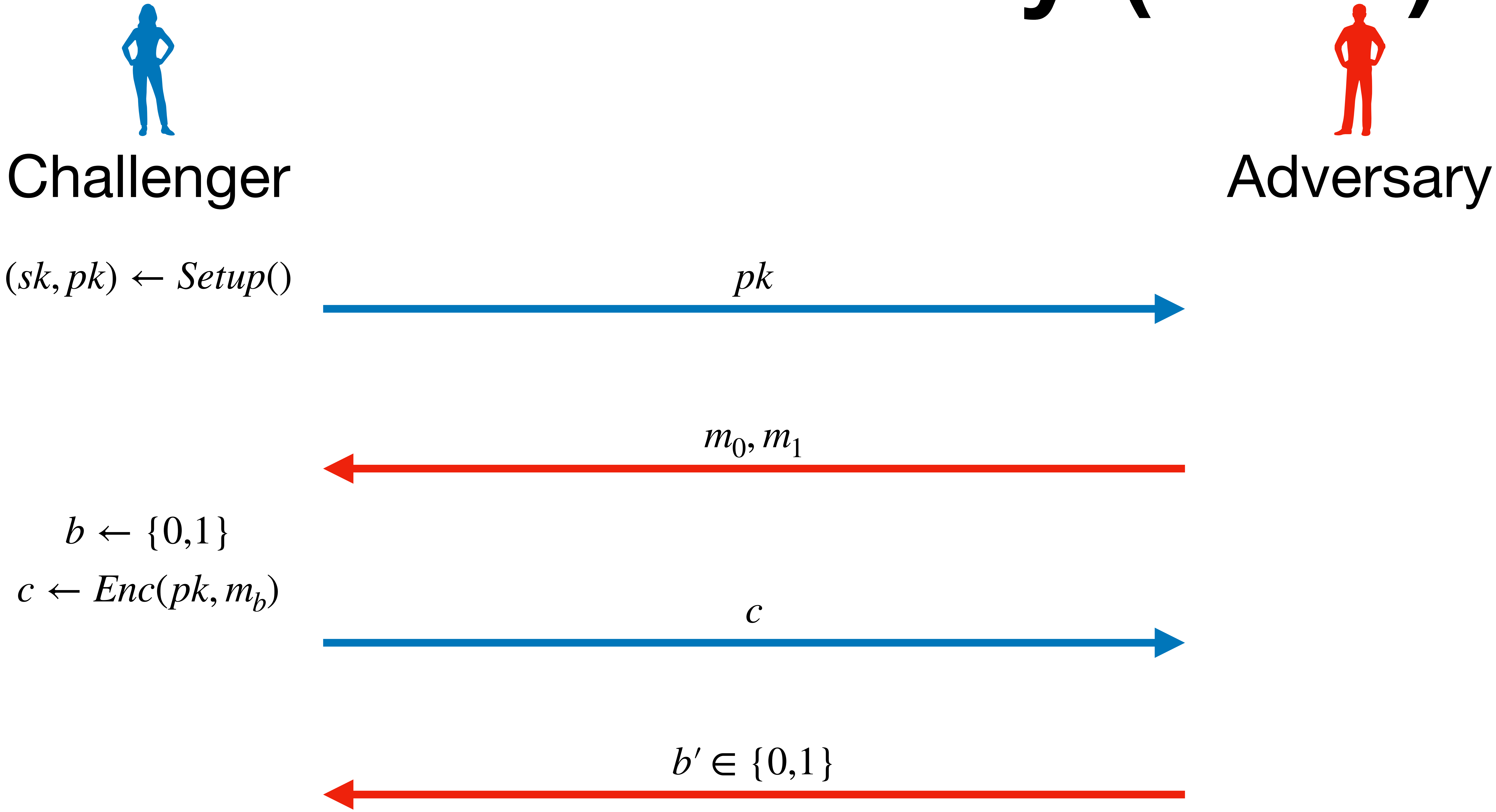
m_0, m_1

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

$c \leftarrow Enc(pk, m_b)$

c

Standard Security (CCA)



Challenger

Adversary

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

pk

m_0, m_1

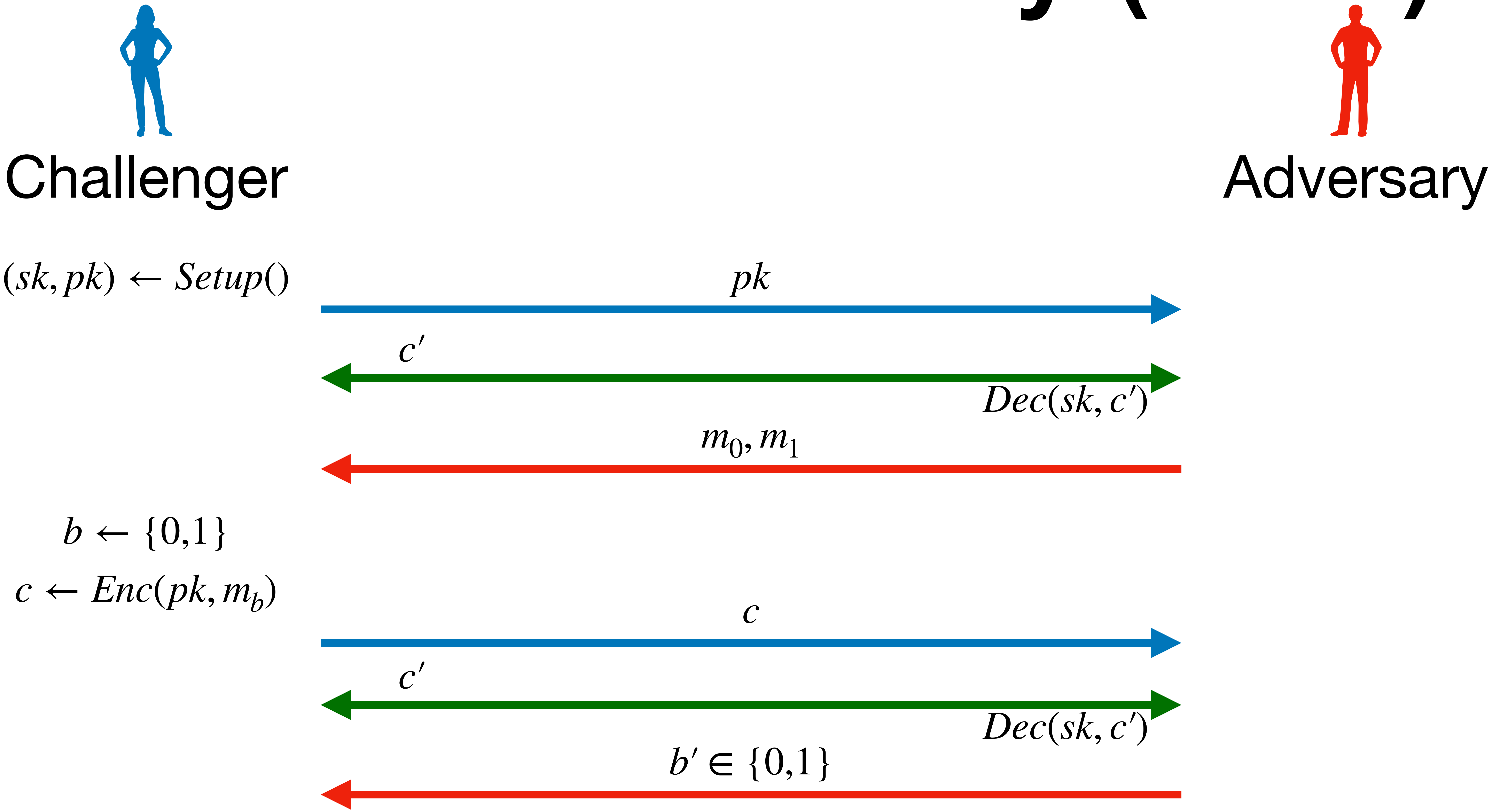
$b \leftarrow \{0,1\}$

$c \leftarrow Enc(pk, m_b)$

c

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

Standard Security (CCA)



Challenger

Adversary

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

pk

c'

$Dec(sk, c')$

m_0, m_1

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

$c \leftarrow Enc(pk, m_b)$

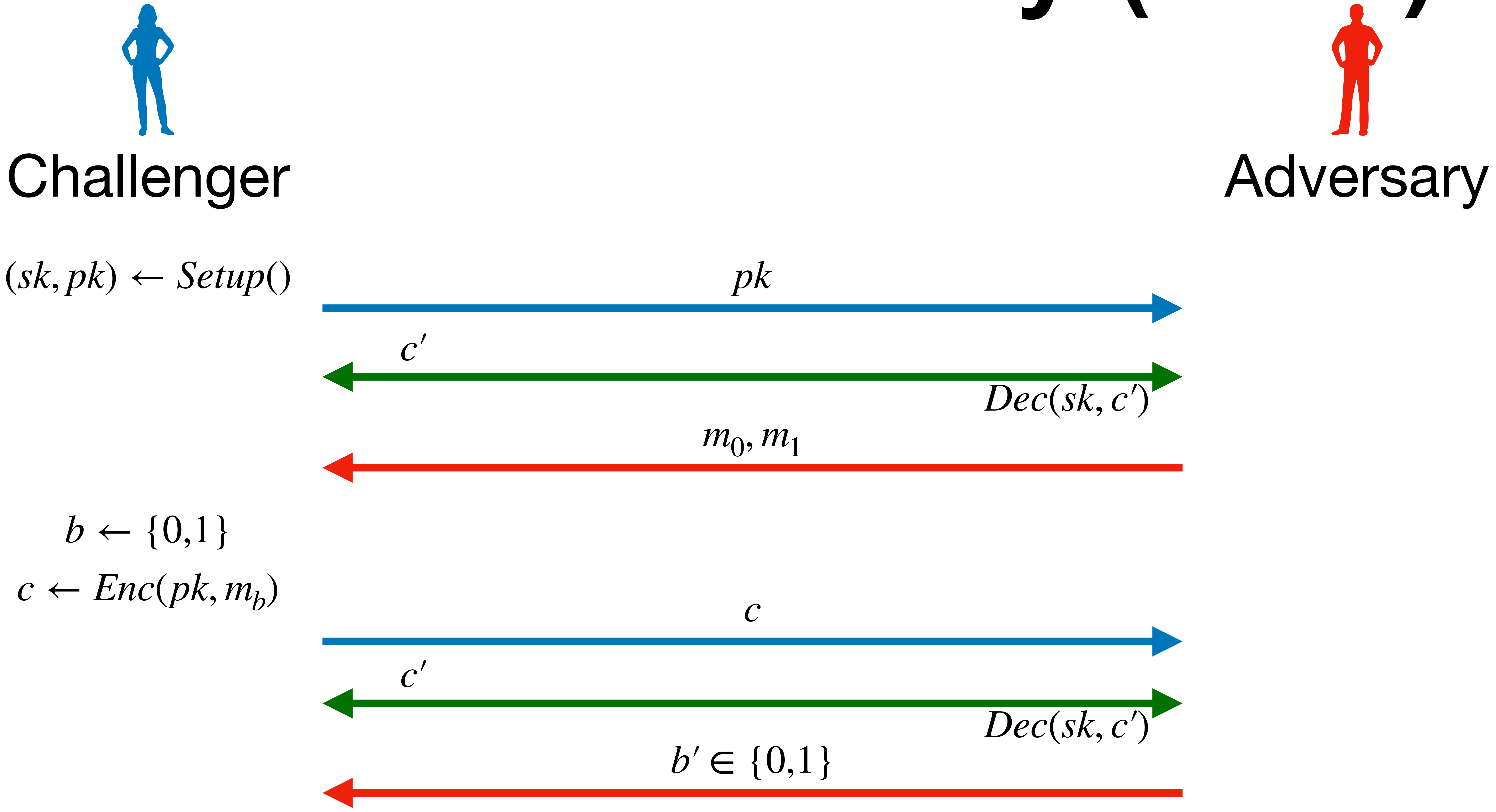
c

c'

$Dec(sk, c')$

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

Standard Security (CCA)


Challenger

Adversary

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

pk

c'

$Dec(sk, c')$

m_0, m_1

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

$c \leftarrow Enc(pk, m_b)$

c

c'

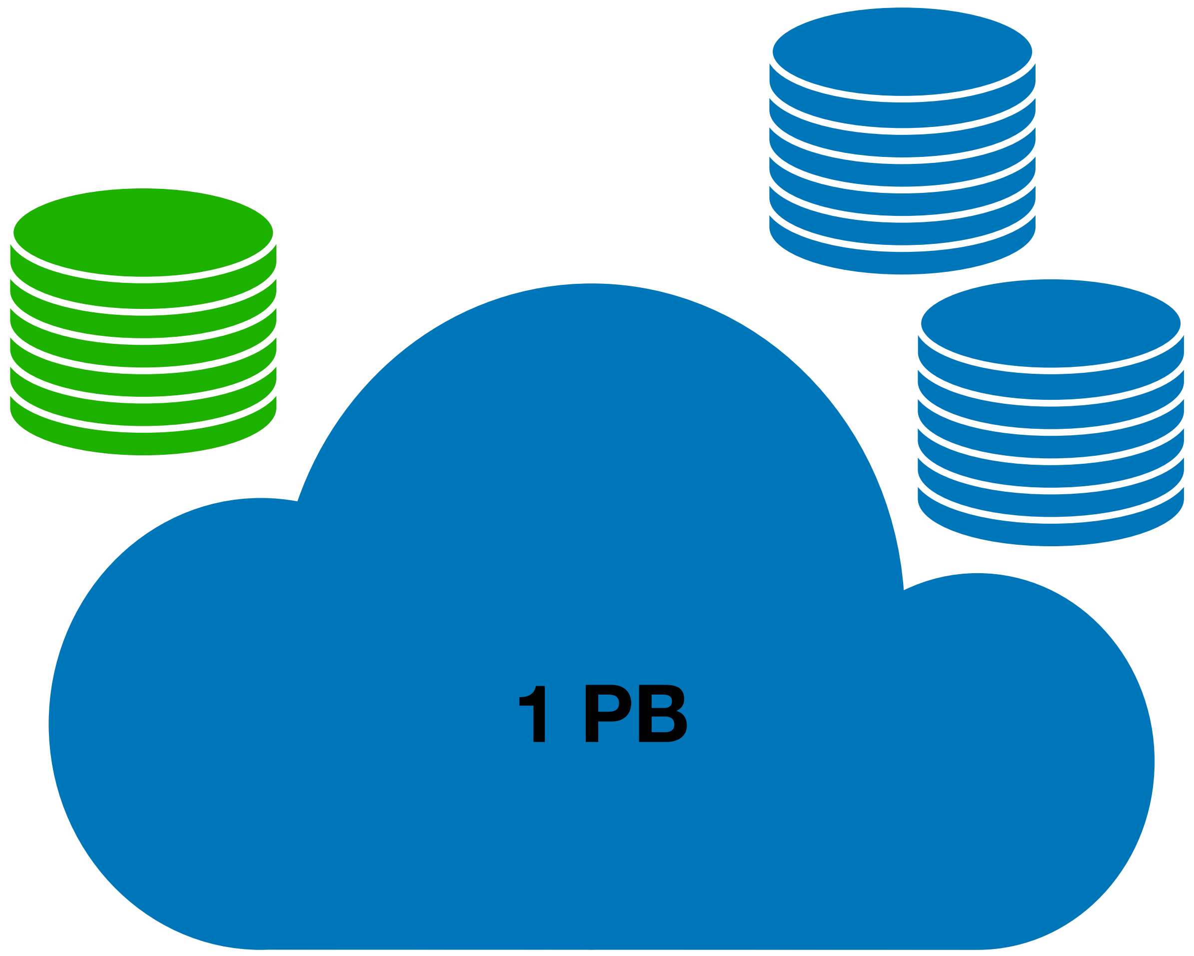
$Dec(sk, c')$

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

Adversary wins if $b = b'$

A Real Life Scenario

A Real Life Scenario



A Real Life Scenario

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Rate 1 Incompressible SKE

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- Due to Guan et al.
- Uses incompressible encoding - no adversary can decode a compressed version of an encoding.
- $Enc(sk = (crs, k), m)$:
  Compute $c_0 = Encode(crs, PRG(s) \oplus m)$.
  Set $c_1 = Ext(c_0; k) \oplus s$.
  Return (c_0, c_1).