COA-Secure Obfuscation and Applications

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International Association for Cryptologic Research

This paper in a nutshell

We provide a **framework** for endowing software obfuscation with "**verifiability**" and "**non-malleability**" guarantees and show **generic constructions satisfying the above guarantees.**

Roadmap

- Motivation
- New Definitions- COA Obfuscation
- New Applications
  - Complete CCA Encryption
  - Stronger (keyless) software watermarking

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- Construction of COA Obfuscation

Program Obfuscation — Boon or Bane for Software Users?

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  - $i\mathcal{O}$ obfuscation of a (puncturable) PRF K might allow an adversary to create an obfuscation of the same function but with key $K+1$

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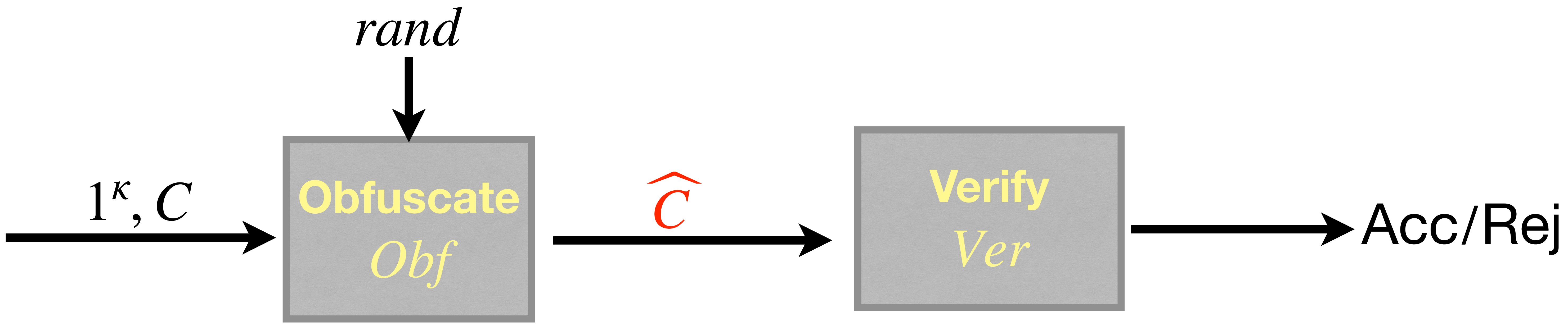

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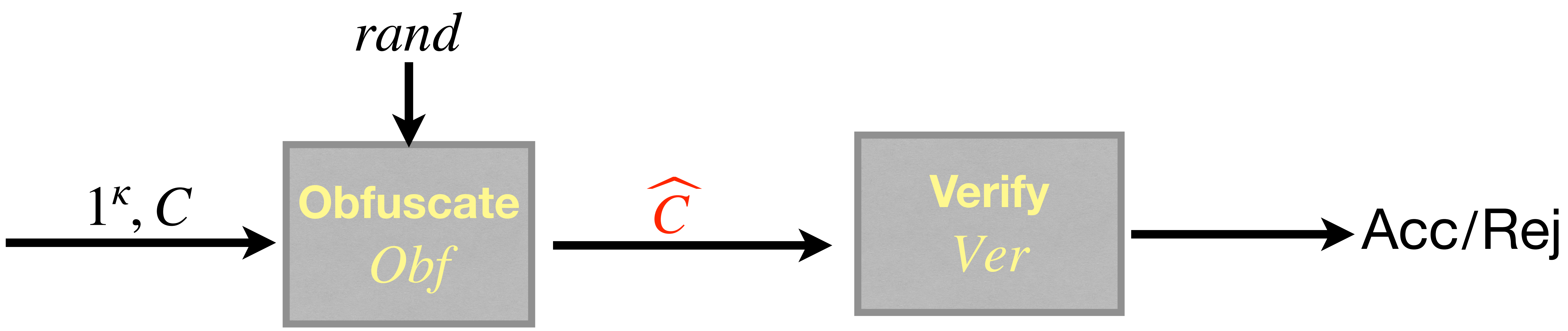

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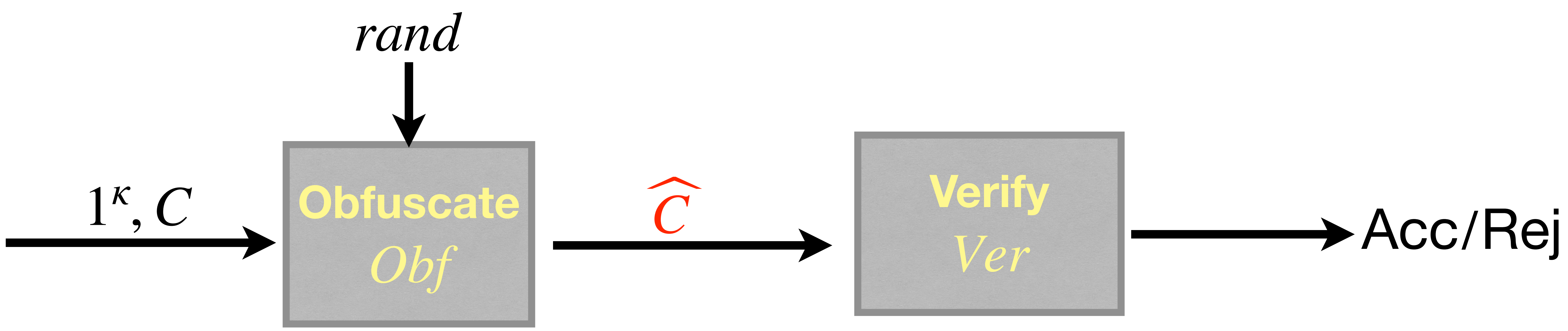

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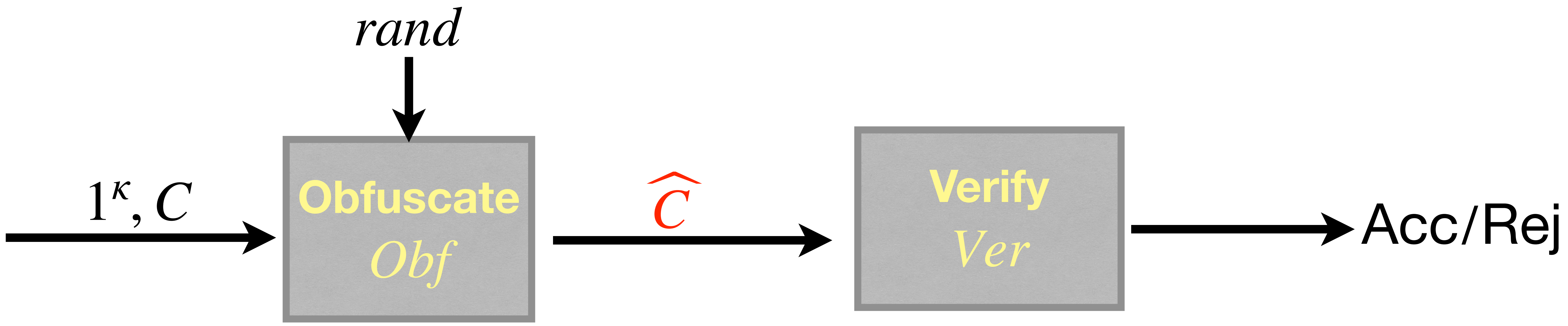

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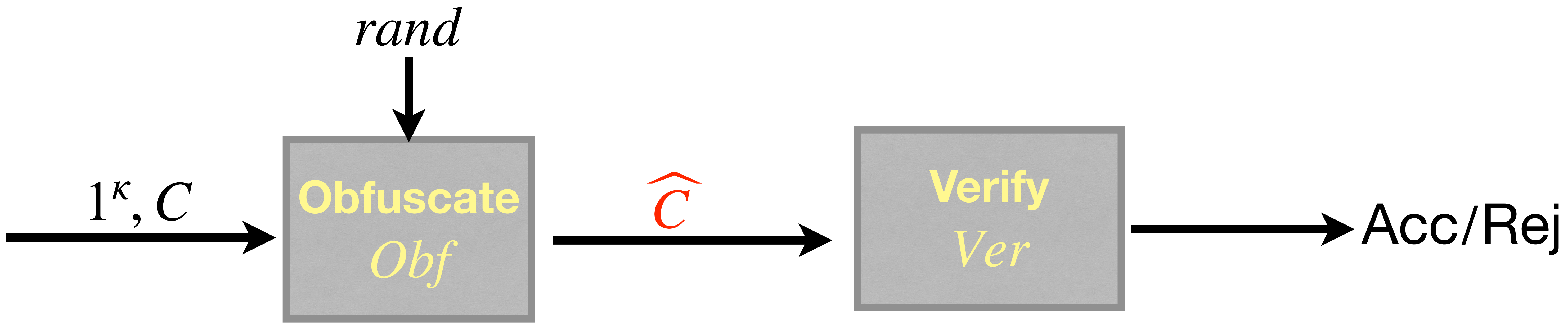

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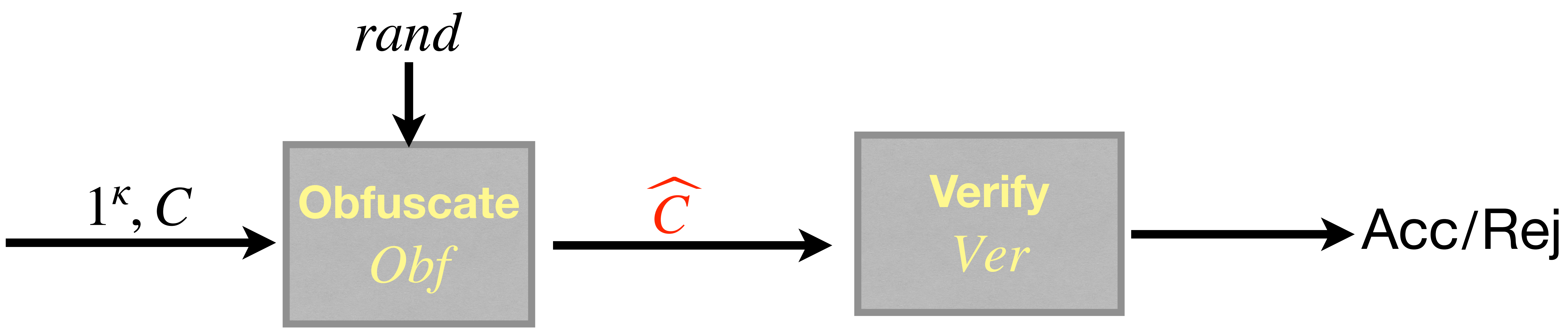

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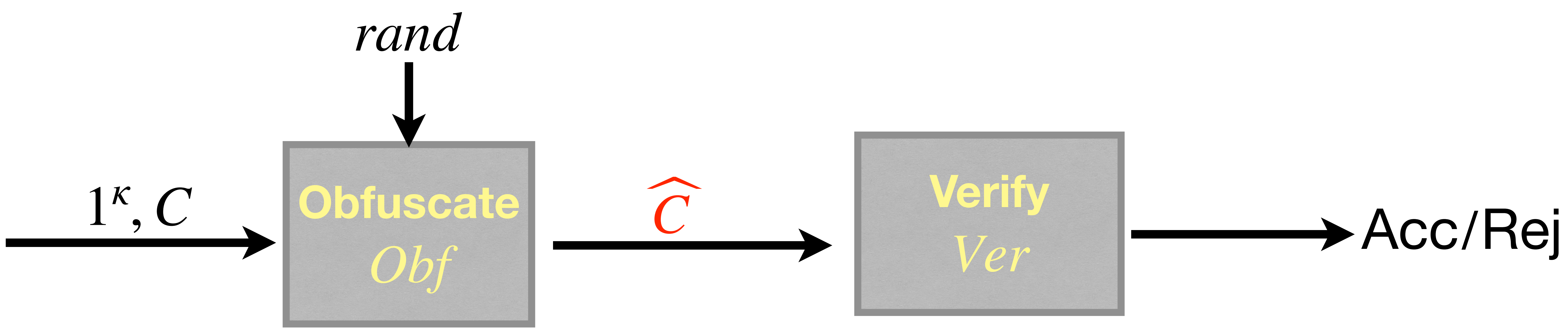

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- **Goal**: Construct verifiable and non-malleable obfuscation in the "plain" model

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  - Considers obfuscation of point functions and related functionalities

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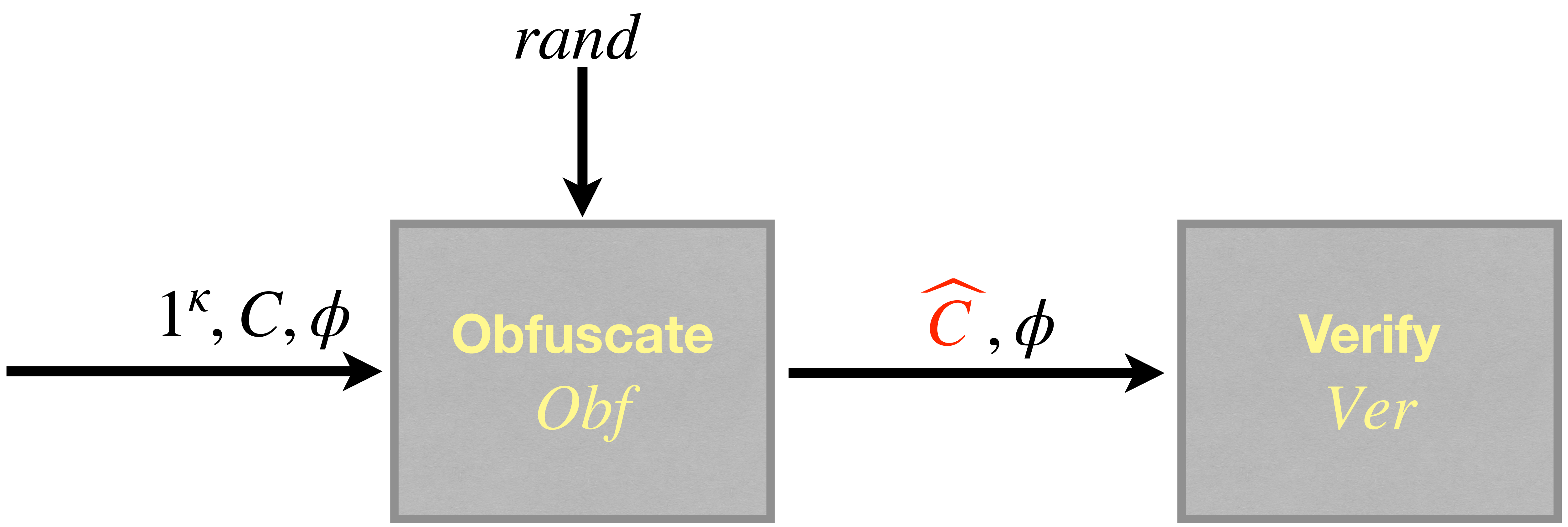

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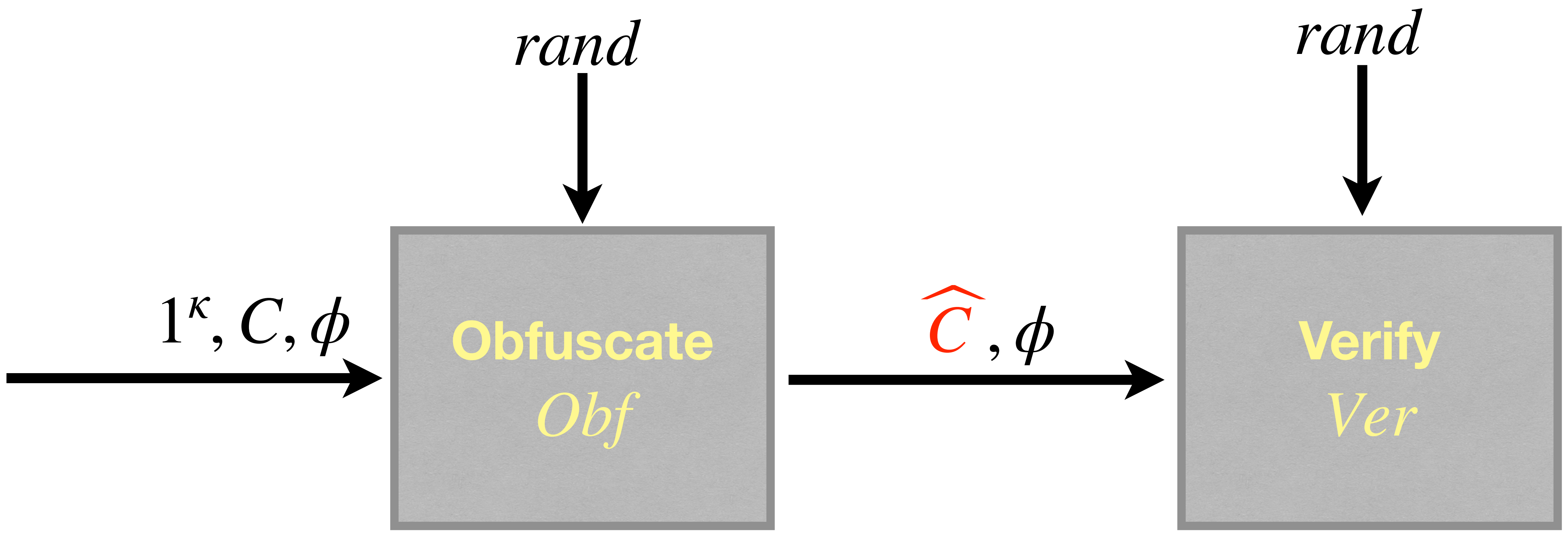

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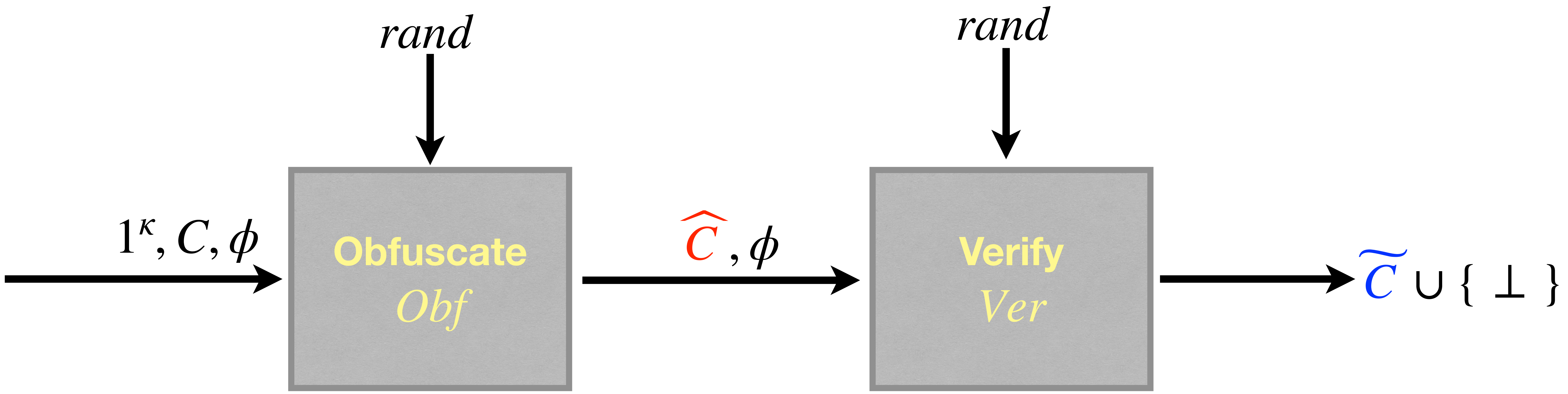

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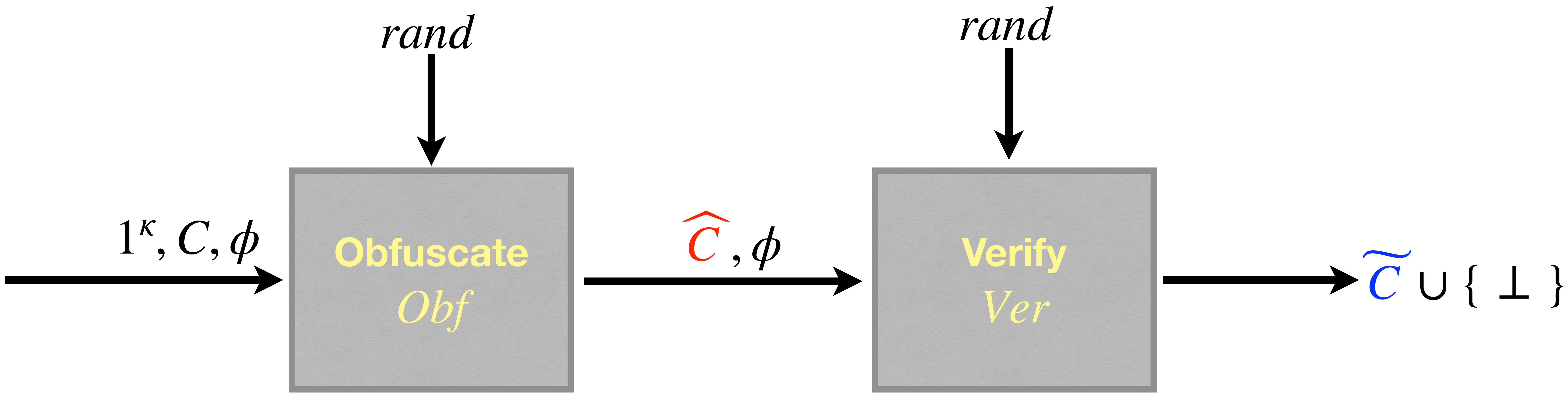

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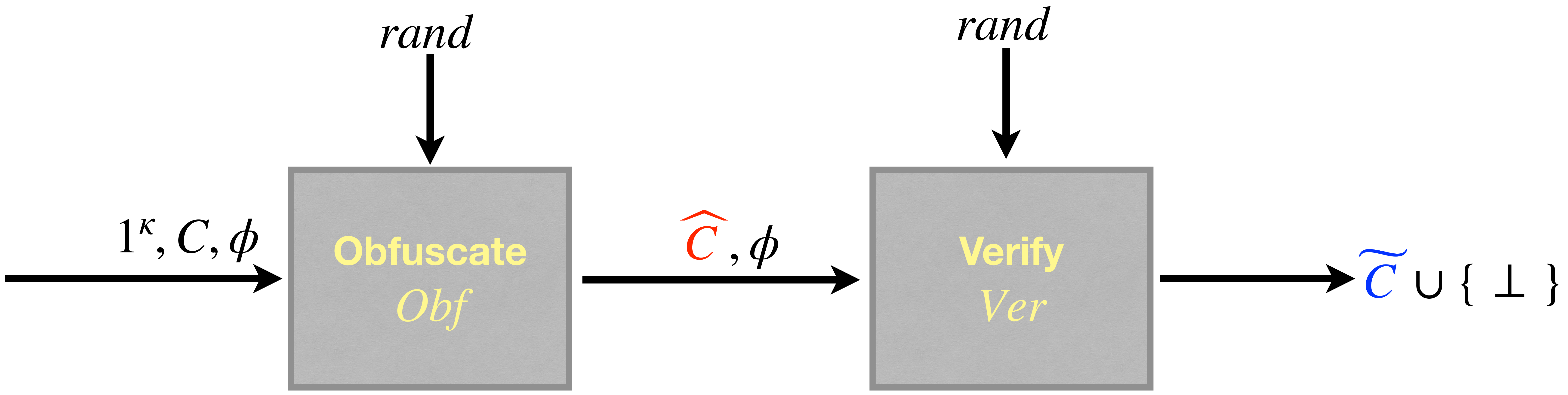

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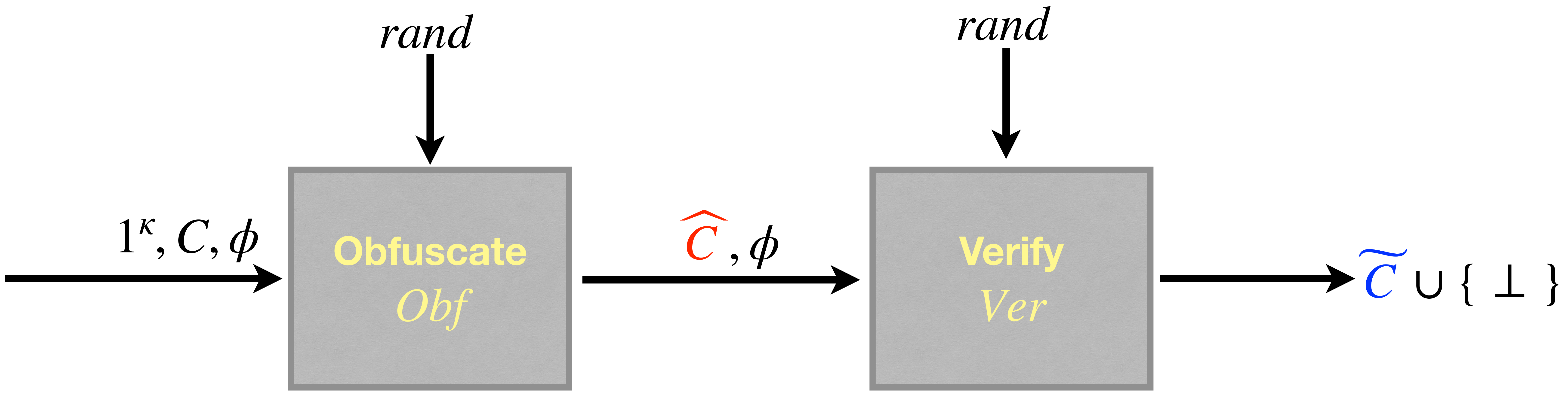

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☑ **COA security**: For "sufficiently similar" circuits C_0 and C_1, $Obf(C_0, \phi) \approx_c Obf(C_1, \phi)$, even given access to a *"de-obfuscation oracle"* $\mathbb{O}(\cdot, \phi)$.

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Challenger

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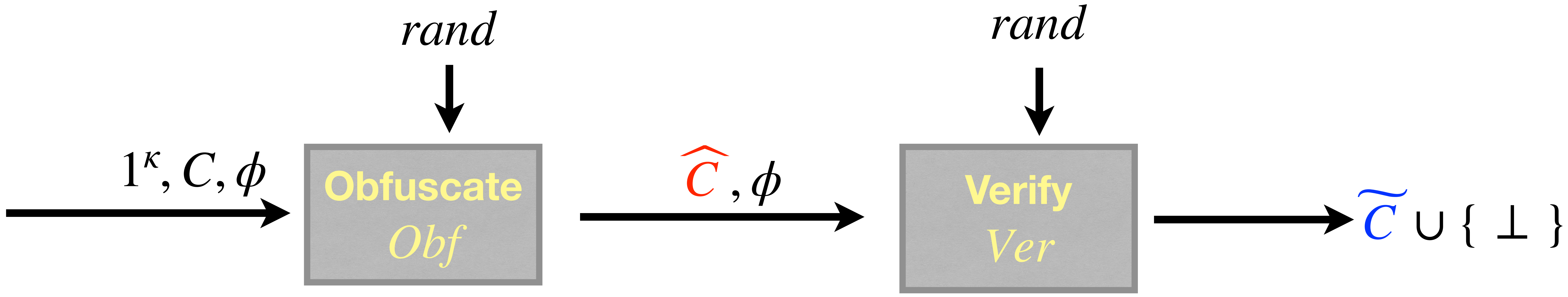

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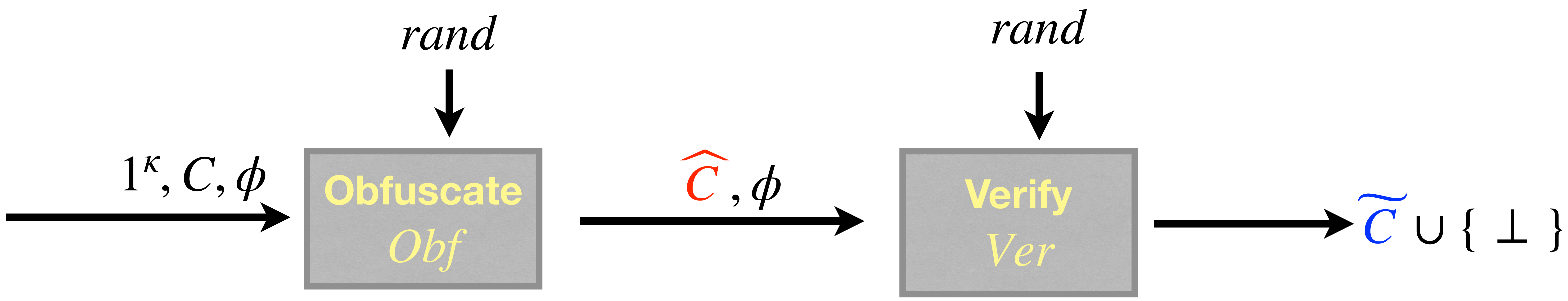

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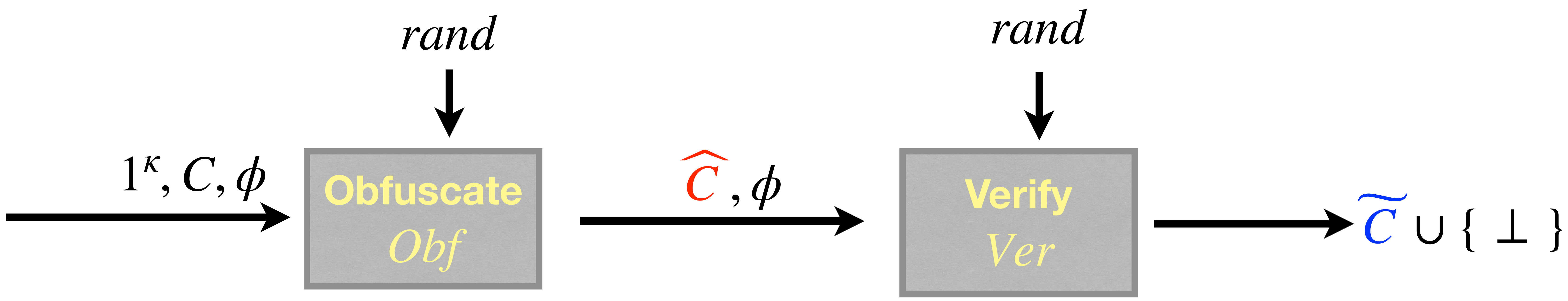

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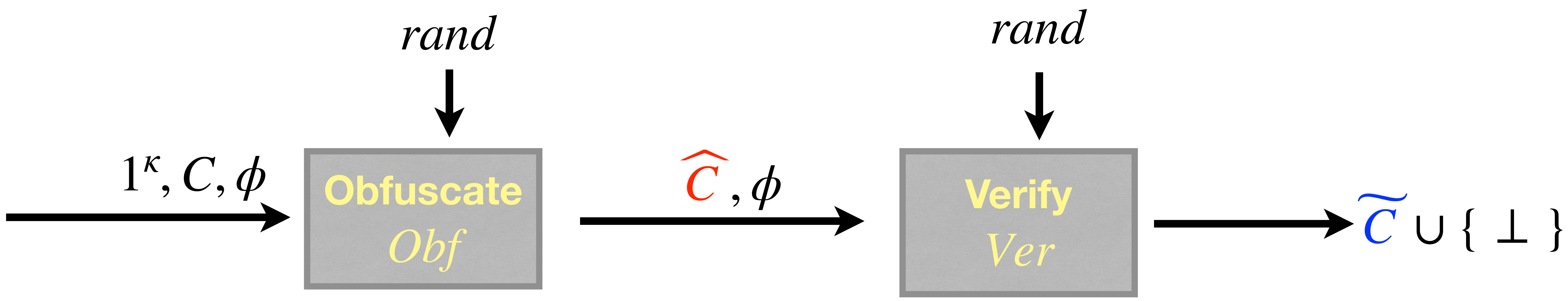

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$$Obf(C_0, \phi) \approx_c Obf(C_1, \phi) \implies \mathcal{O}(C_0) \approx_c \mathcal{O}(C_1)$$

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Challenger

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

(C_0, C_1, z) →

← $\widehat{C}$

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$\widehat{C}$ →

Samp must be an admissible ϕ-satisfying sampler

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De-obfuscation queries can be made adaptively and in arbitrary order

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The De-obfuscation oracle $\mathbb{O}(\cdot, \phi)$

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Consider a class of circ… bfuscation scheme.

COA Fortification for injective PiO => Def. 1

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Applications of COA Obfuscation

Complete CCA (CCCA)-secure Public Key Encryption

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    - $\forall$ "non-useless" keys pk, $\exists$ "opening" sk s.t. $\mathsf{Dec}(sk, \mathsf{Enc}(pk, m)) = m$ w.h.p. Further, $\exists$ pk' s.t. $(pk', sk) \leftarrow \text{KeyGen}(1^\kappa; r)$.

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Challenger

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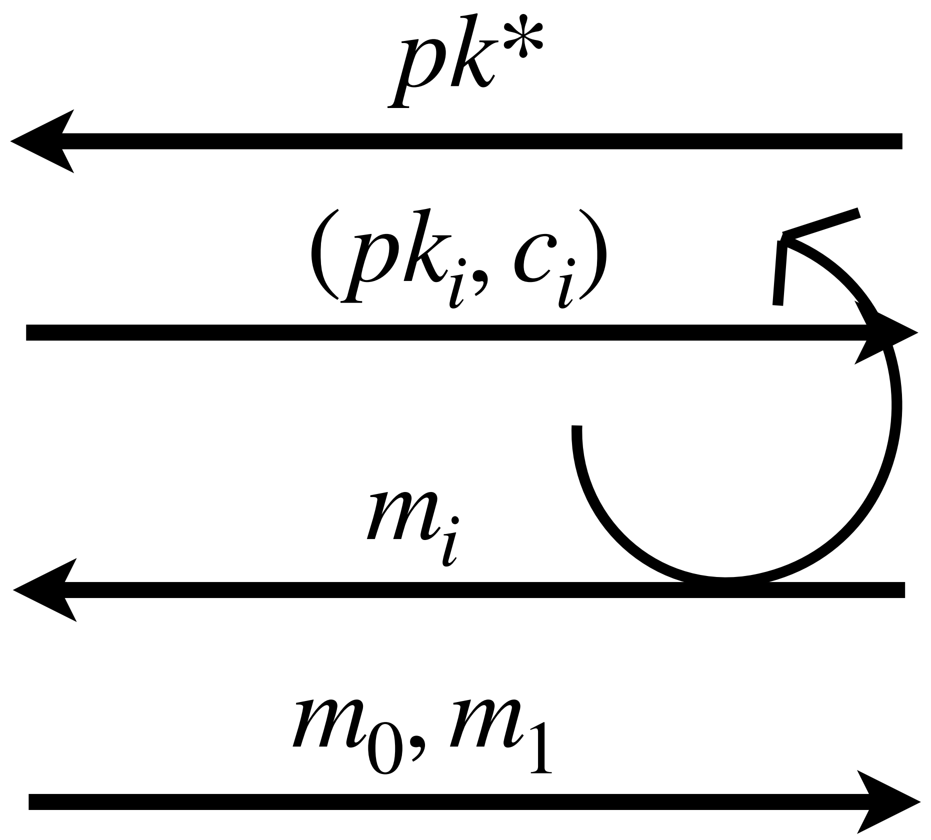

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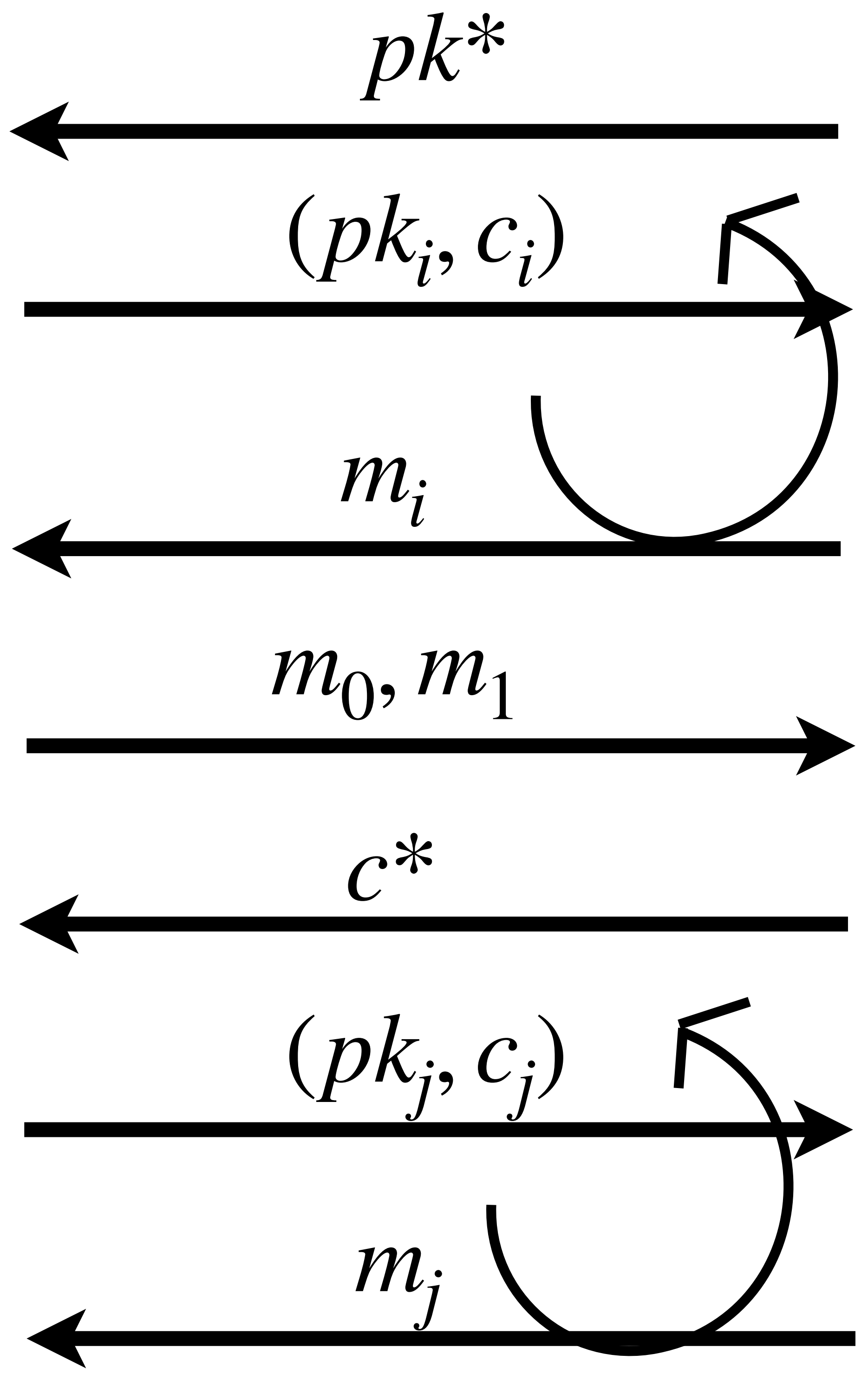

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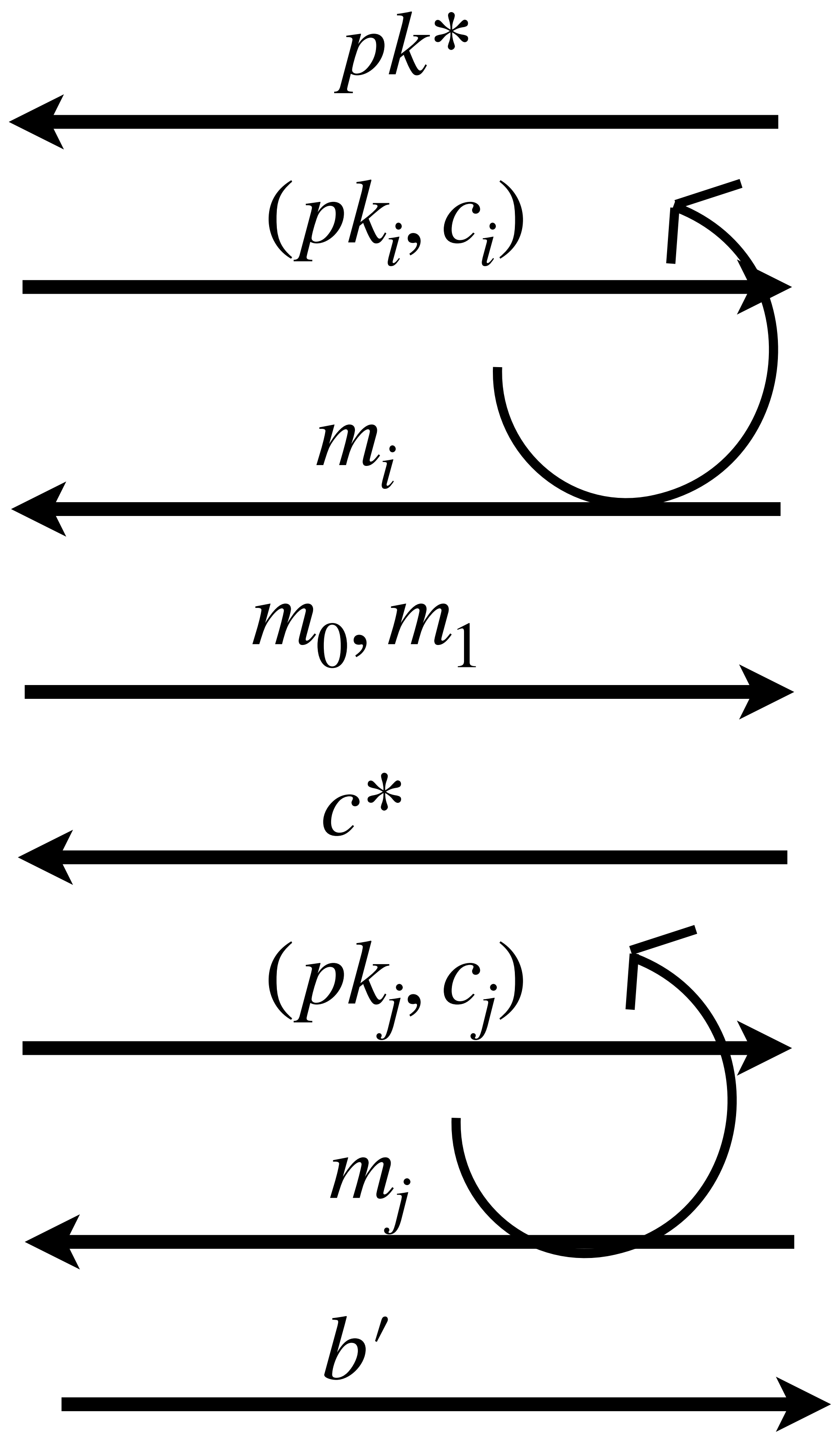

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Zooming into the proof of CCCA-secure PKE

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1. Constants: K_1, K_2
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Program P_{K_1,K_2}

Zooming into the proof of CCCA-secure PKE

Either of the following two cases may arise (for each decryption query):

1. $(pk, c) \neq (pk^*, c^*)$ and $pk_i = pk^*$: In this case this can be reduced to the CCA-security of the [SW'14] construction.

2. $(pk, c) \neq (pk^*, c^*)$ and $pk \neq pk^*$: In this case, letting $pk = \widehat{P}$:

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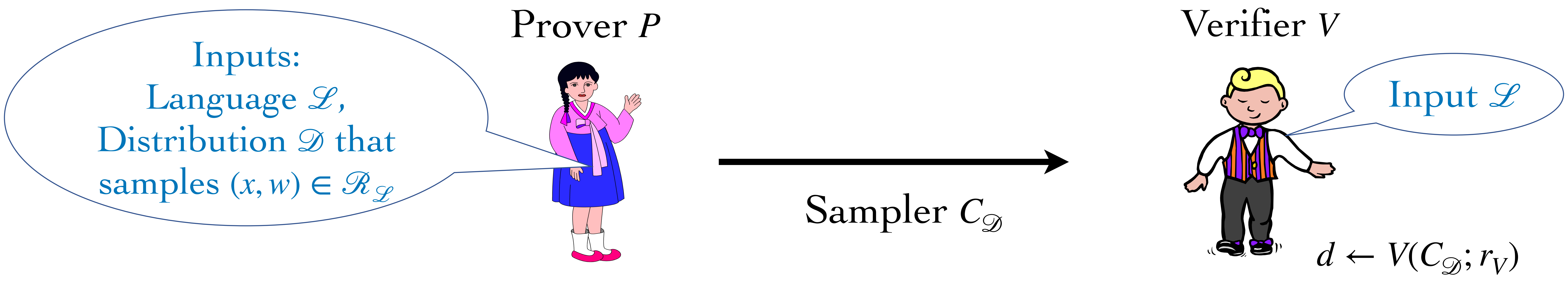

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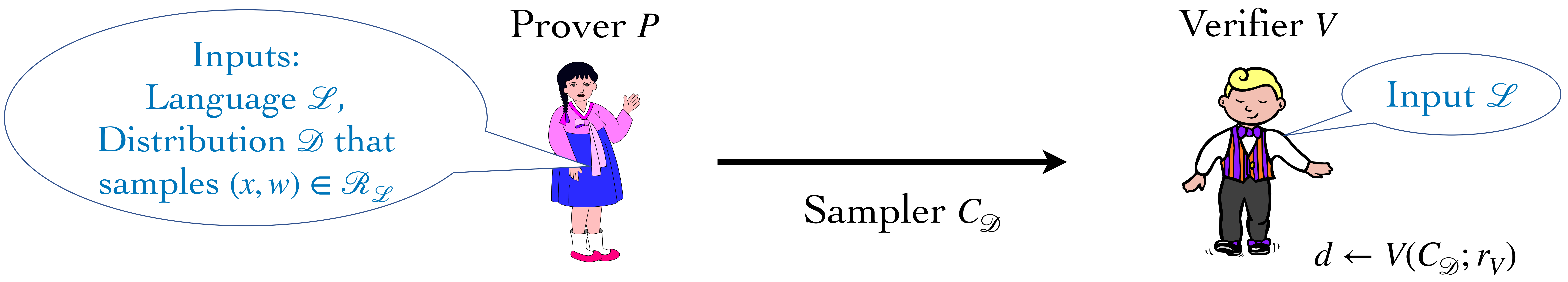

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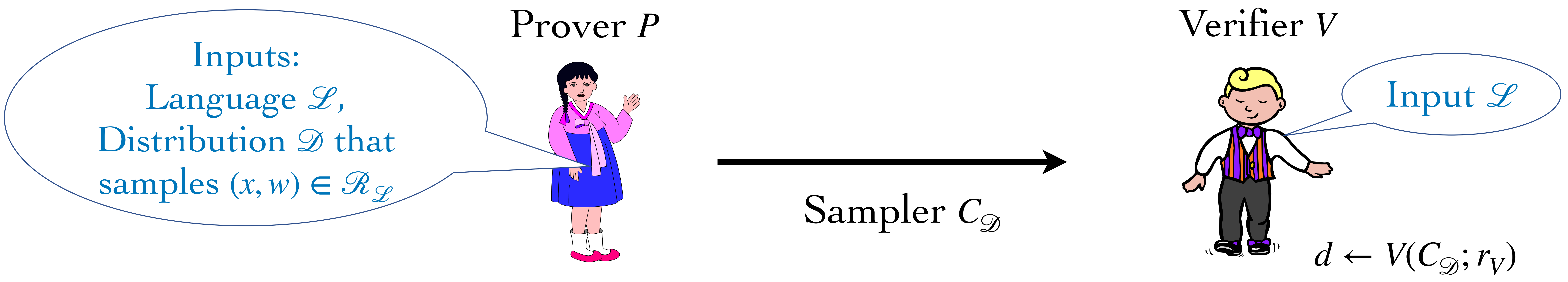

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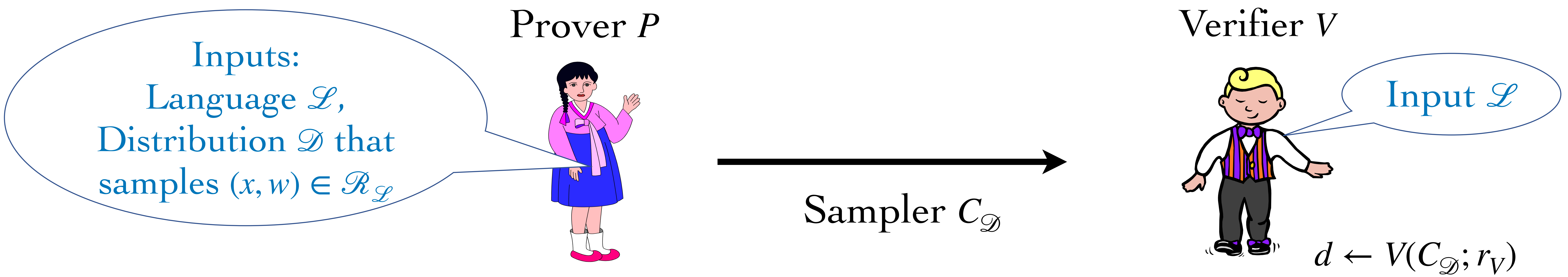

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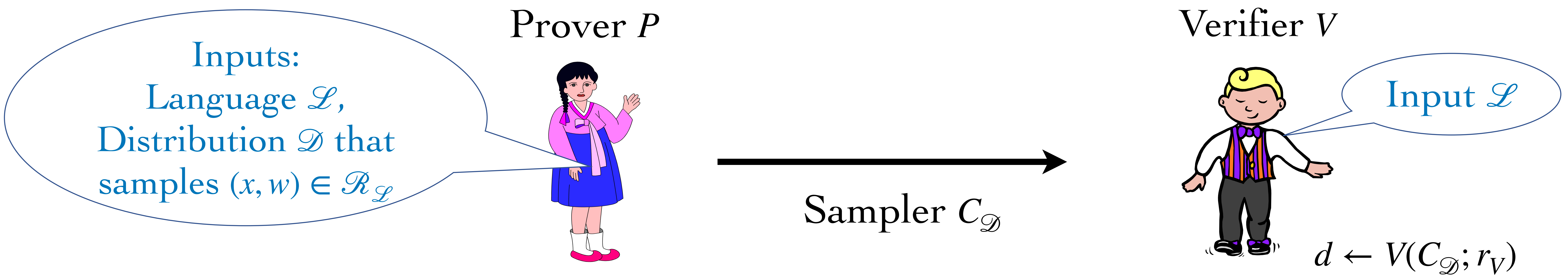

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Theorem: Assuming sub-exp $i\mathscr{O}$ and sub-exp secure OWF, there exists NIDI arguments for NP.

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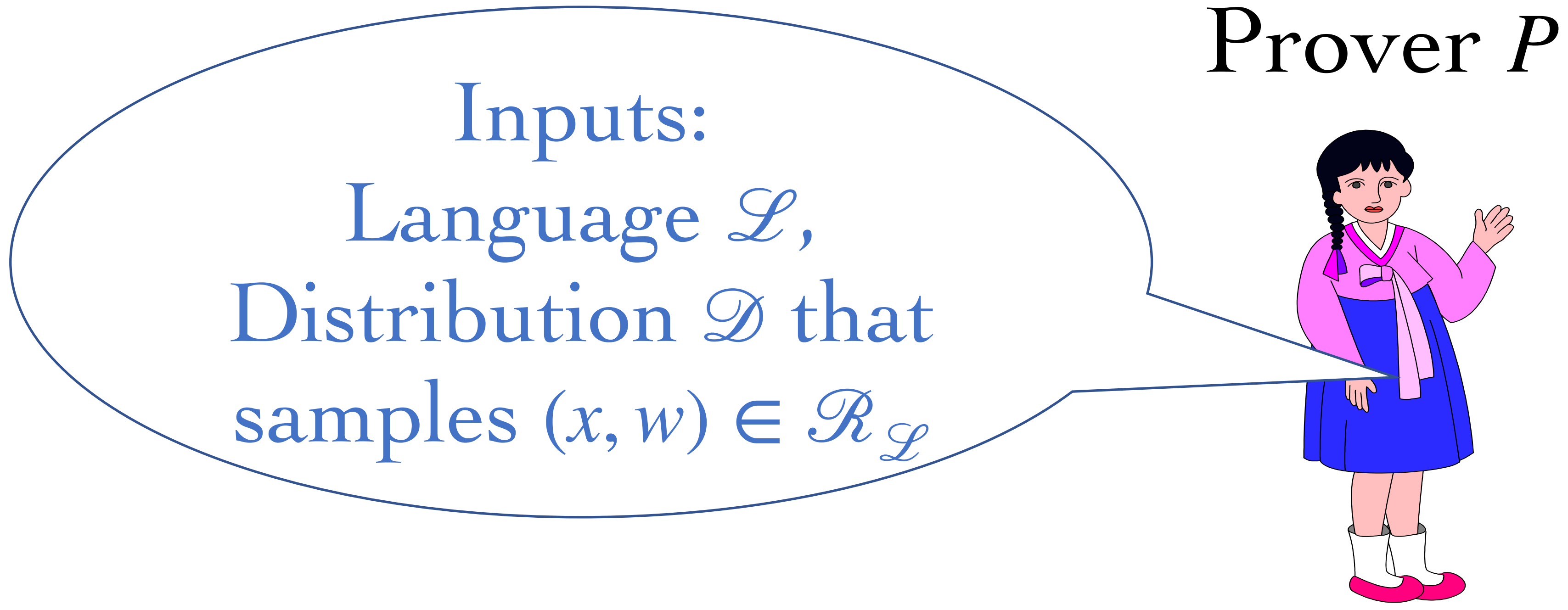

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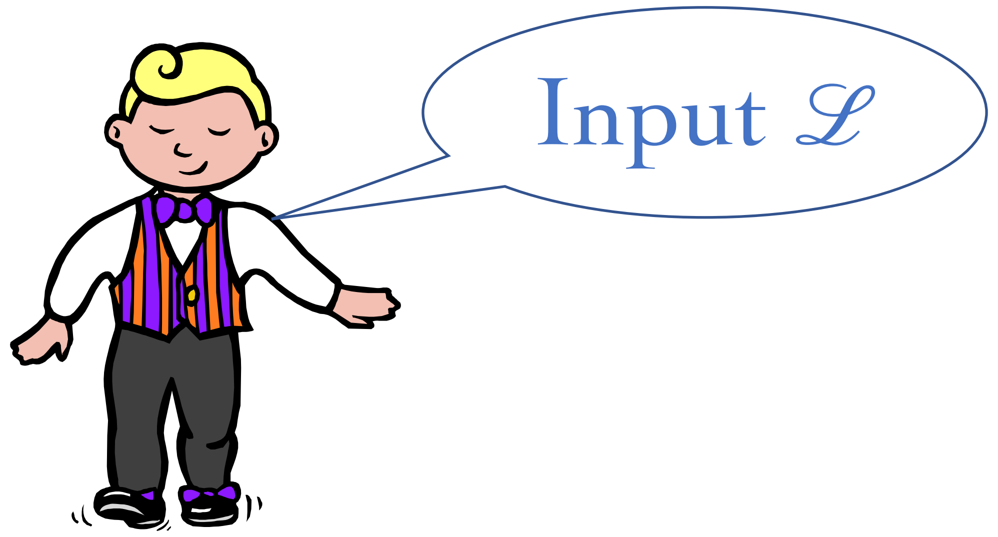

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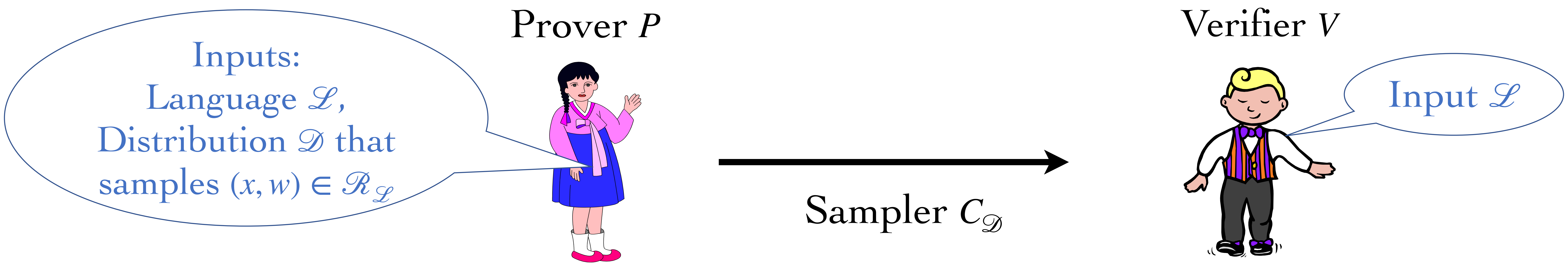

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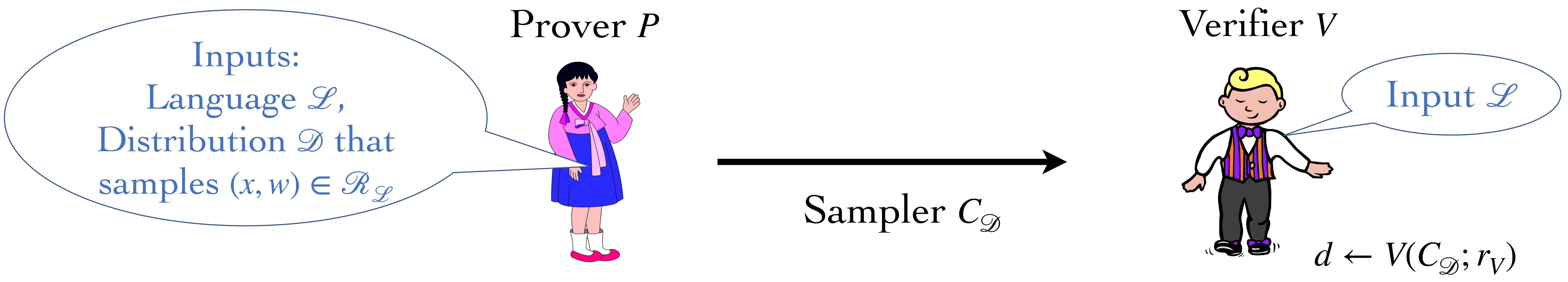

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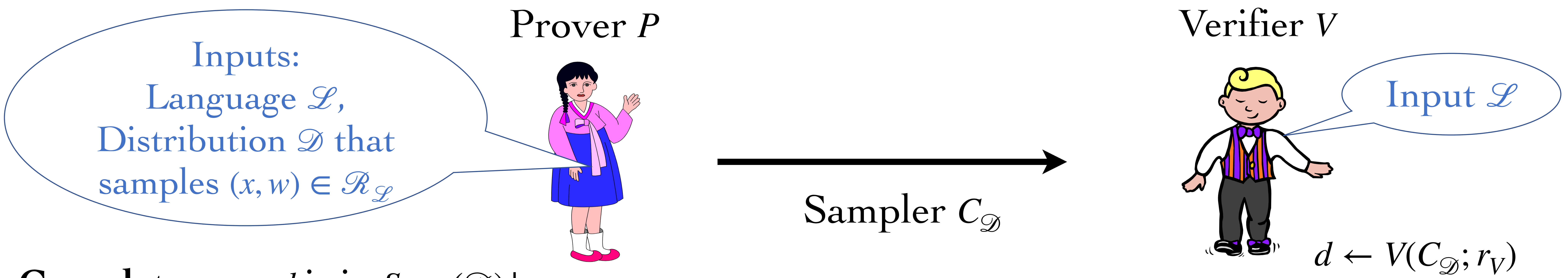

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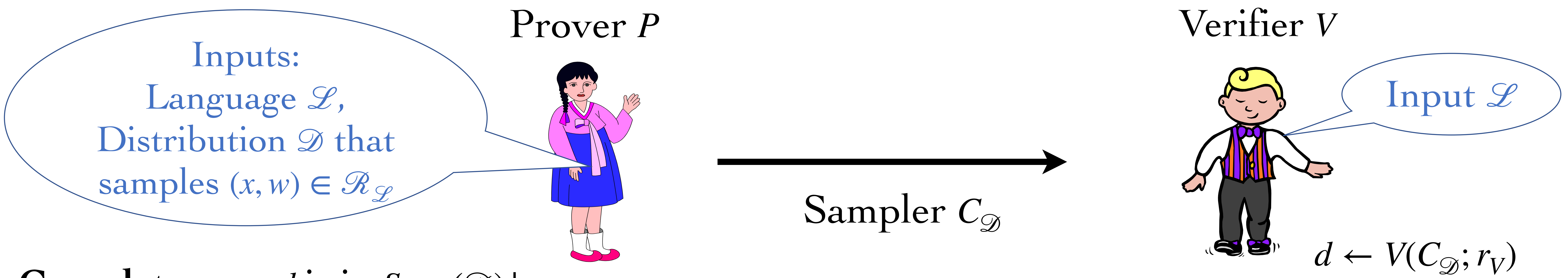

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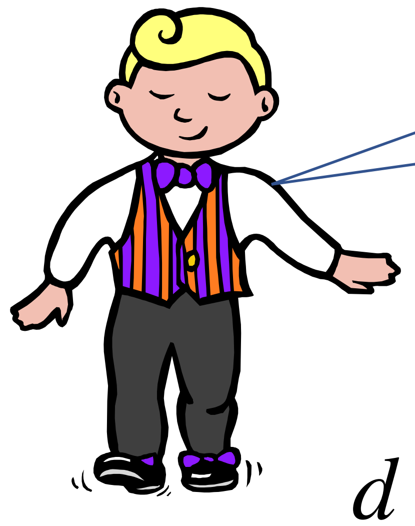
Inputs:
Language $\mathscr{L}$,
Distribution $\mathscr{D}$ that
samples $(x, w) \in \mathscr{R}_{\mathscr{L}}$

Sampler $C_{\mathscr{D}}$

Verifier V

Input $\mathscr{L}$



$d \leftarrow V(C_{\mathscr{D}}; r_V)$

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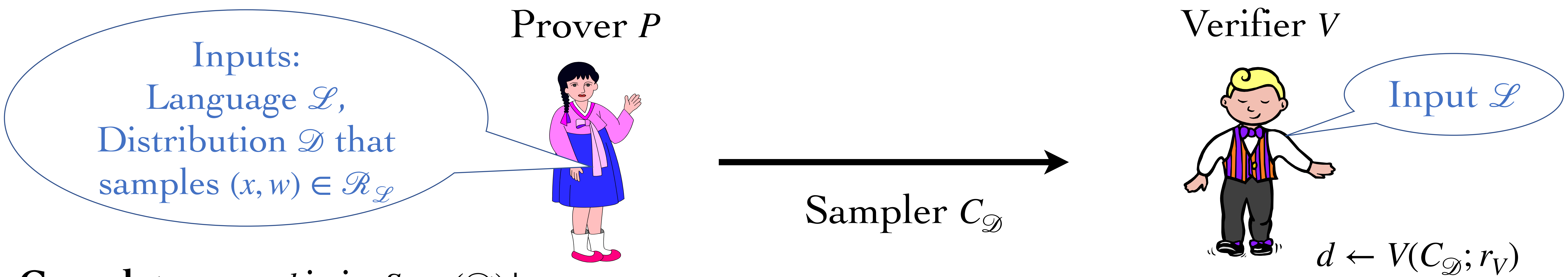

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We construct r-NIDI arguments by modifying the [K’21] construction by making the underlying primitives to be secure in the presence of $\mathbb{O}$ (using complexity leveraging).

Construction of COA secure Obfuscation

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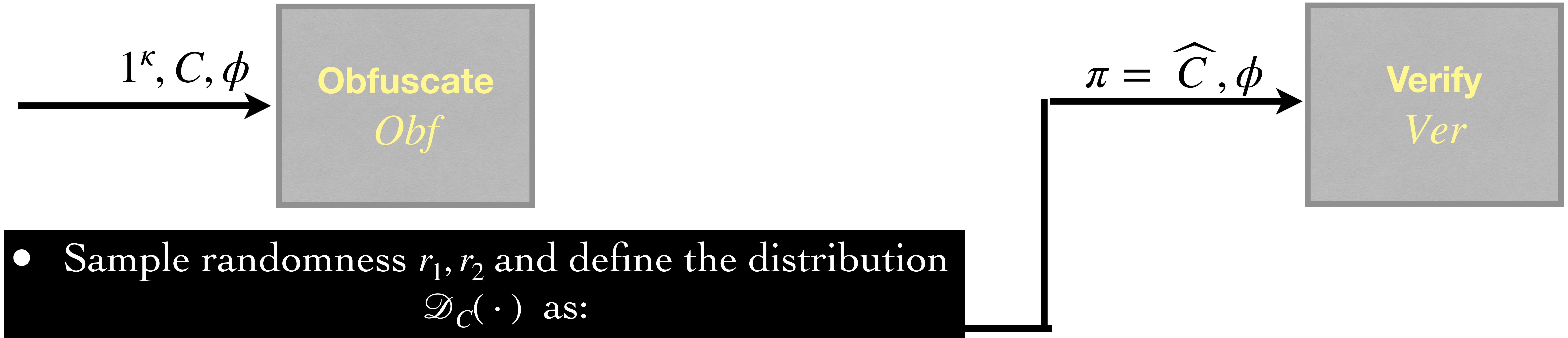

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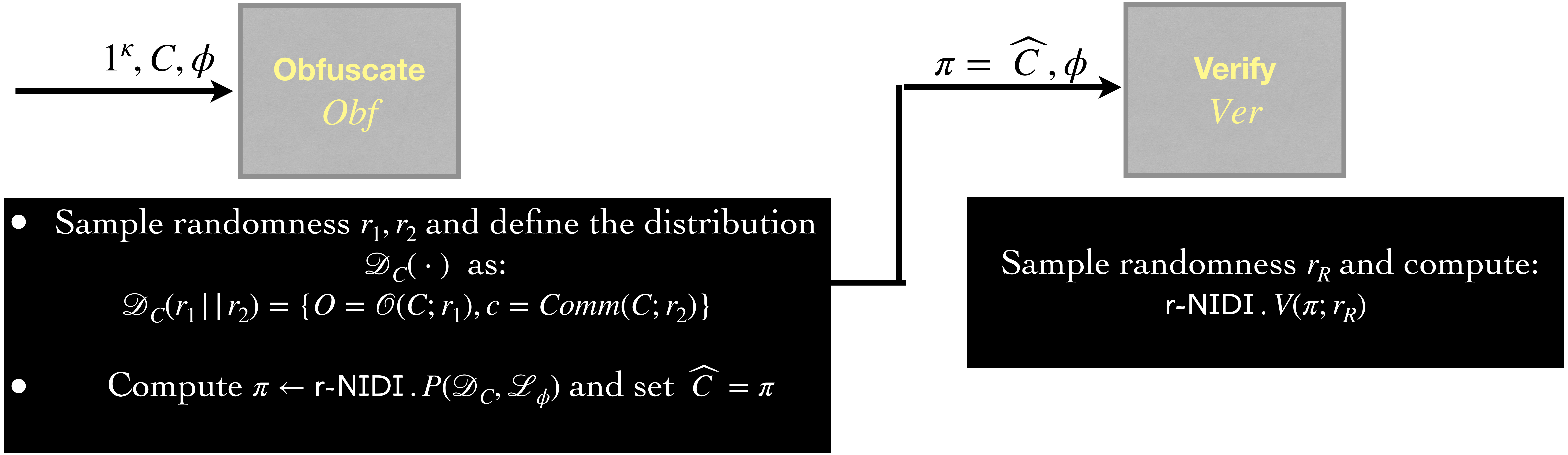

Zooming into the proof of our COA construction

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Claim: Hybrid 0 $\approx_c$ Hybrid 1 => Follows from the "soundness" of r-NIDI + "perfect infectivity" of $\mathcal{O}$ + "non-malleability" of CCACom

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- **Hybrid 12**: Obfuscate $\mathbf{C_1}$ and commit to $\mathbf{C_0}$. De-obfuscation oracle is implemented using *Decomm*.

$O^* = \mathcal{O}(\mathbf{C_1})$ $\quad c^* = Comm(\mathbf{C_0})$

$$\mathcal{D}_{C_0, C_1}(r_1 || r_2) = \{O = \mathcal{O}(\mathbf{C_1}; r_1), c = Comm(\mathbf{C_0}; r_2)\}$$

Zooming into the proof of our COA construction

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Claim: Hybrid 12 $\approx_c$ Hybrid 2 => Follows from the (T, ϵ)-security of $\mathscr{O}$.

Open Problems

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- Construct COA-secure obfuscation for the more traditional definition (where the verifier is deterministic)?

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- More applications of COA-secure Obfuscation?


THANK
YOU!


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