Zero-Knowledge Proofs

Lecture 15

Interactive Proofs

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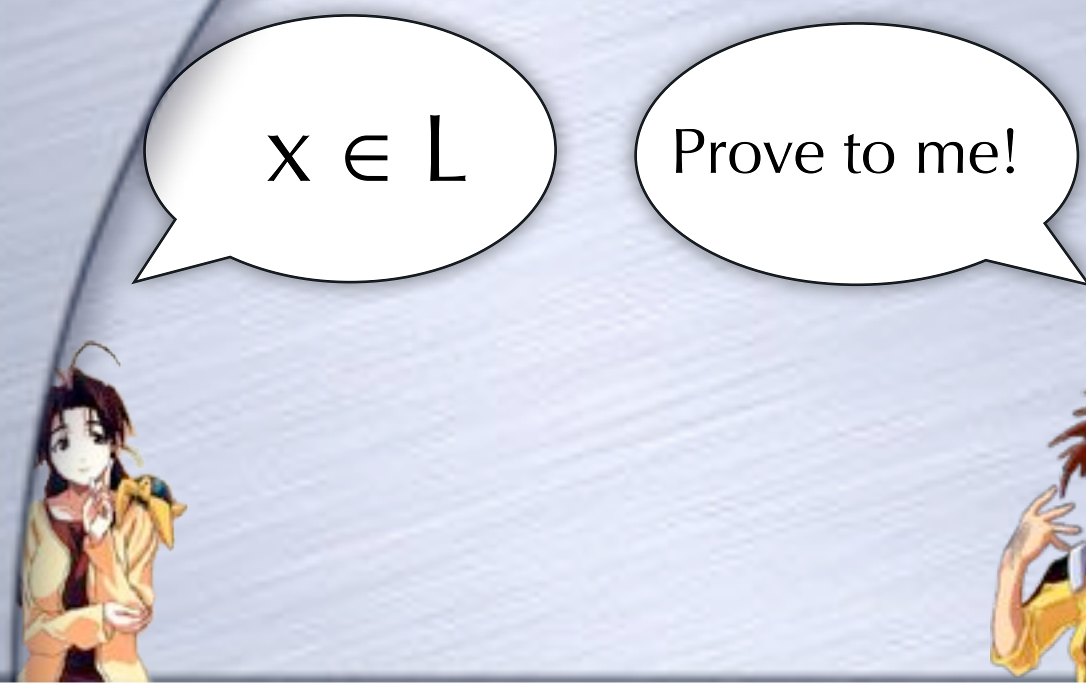

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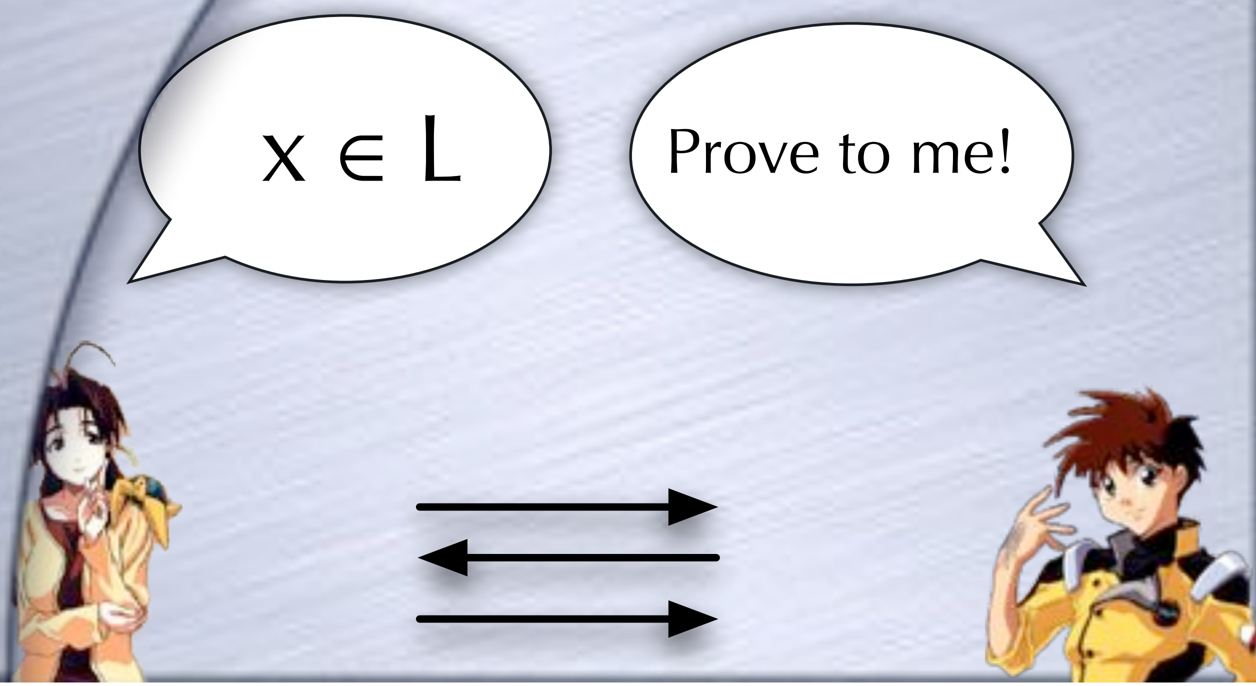

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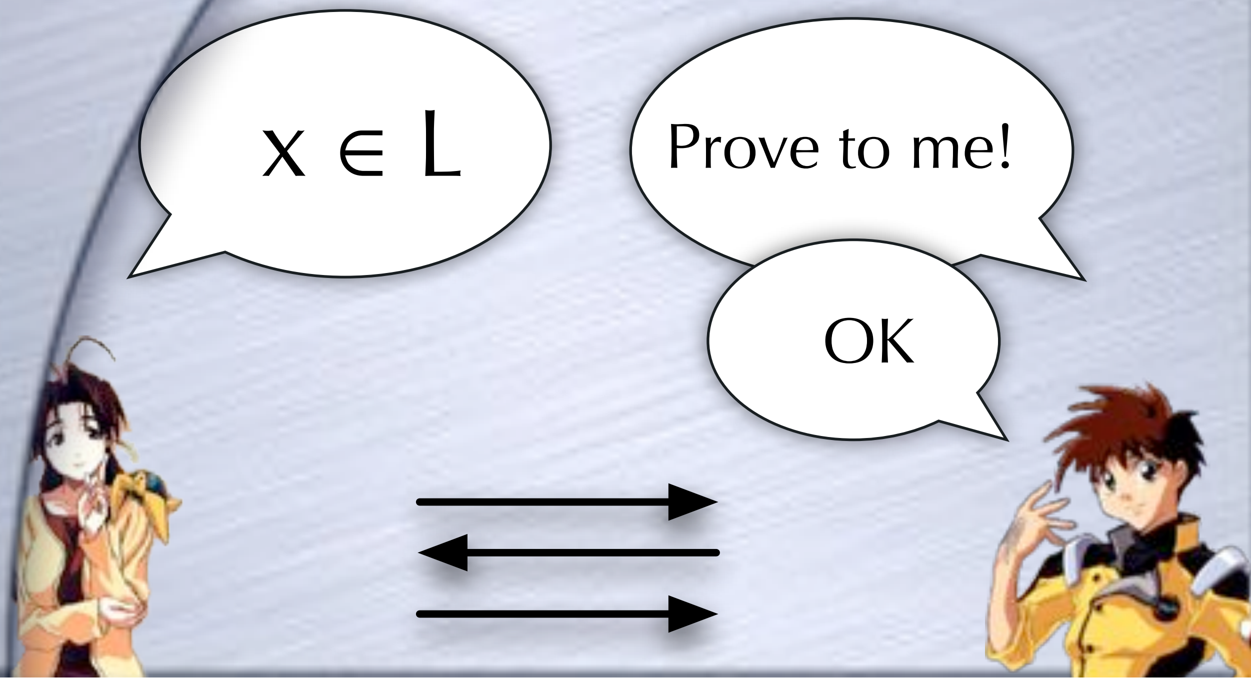

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- ***Prover*** wants to convince ***verifier*** that x has some property
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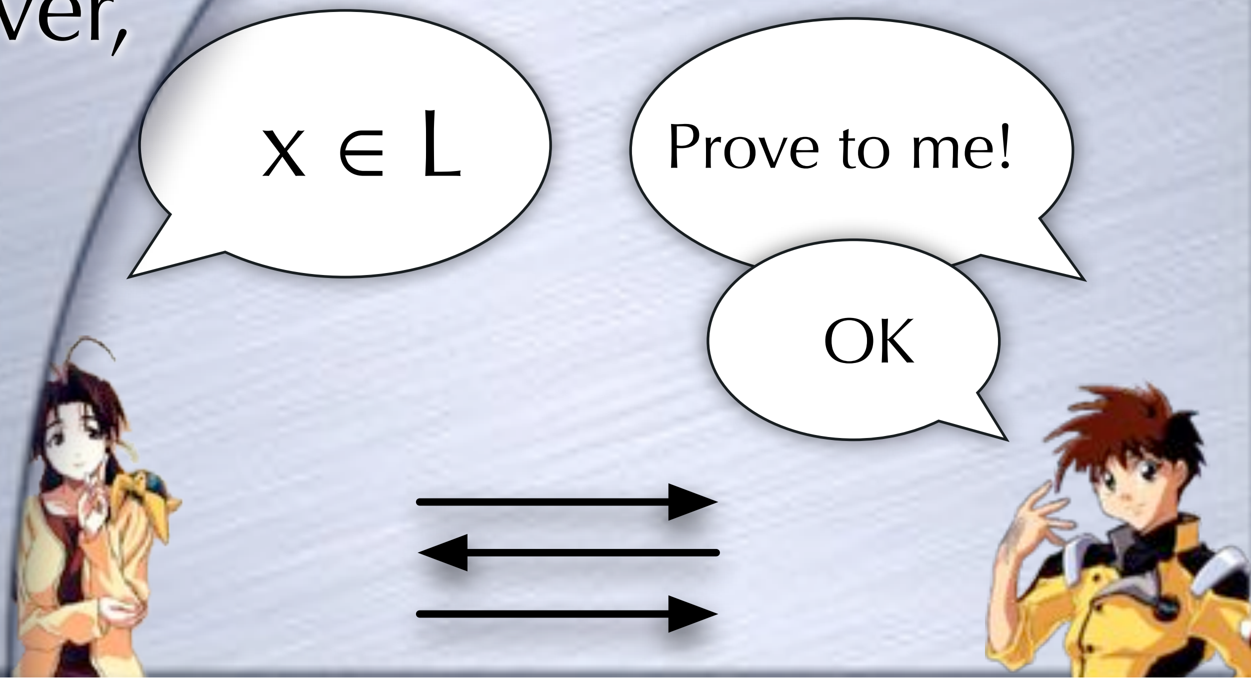
- All powerful prover, computationally bounded verifier (for now)



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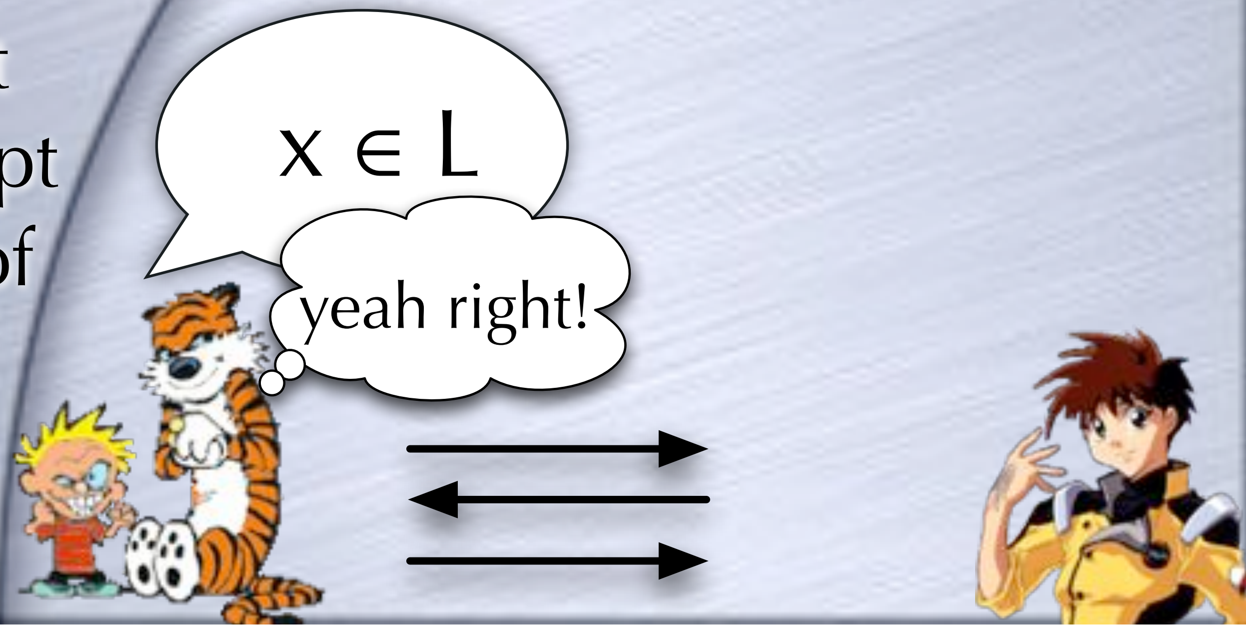

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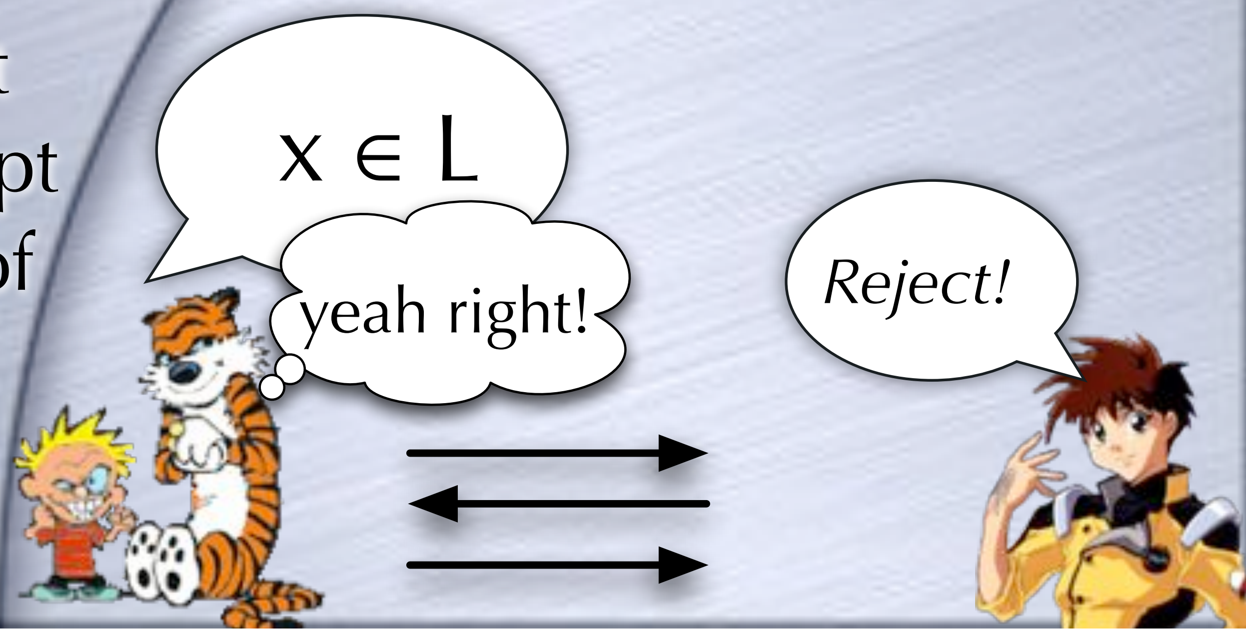

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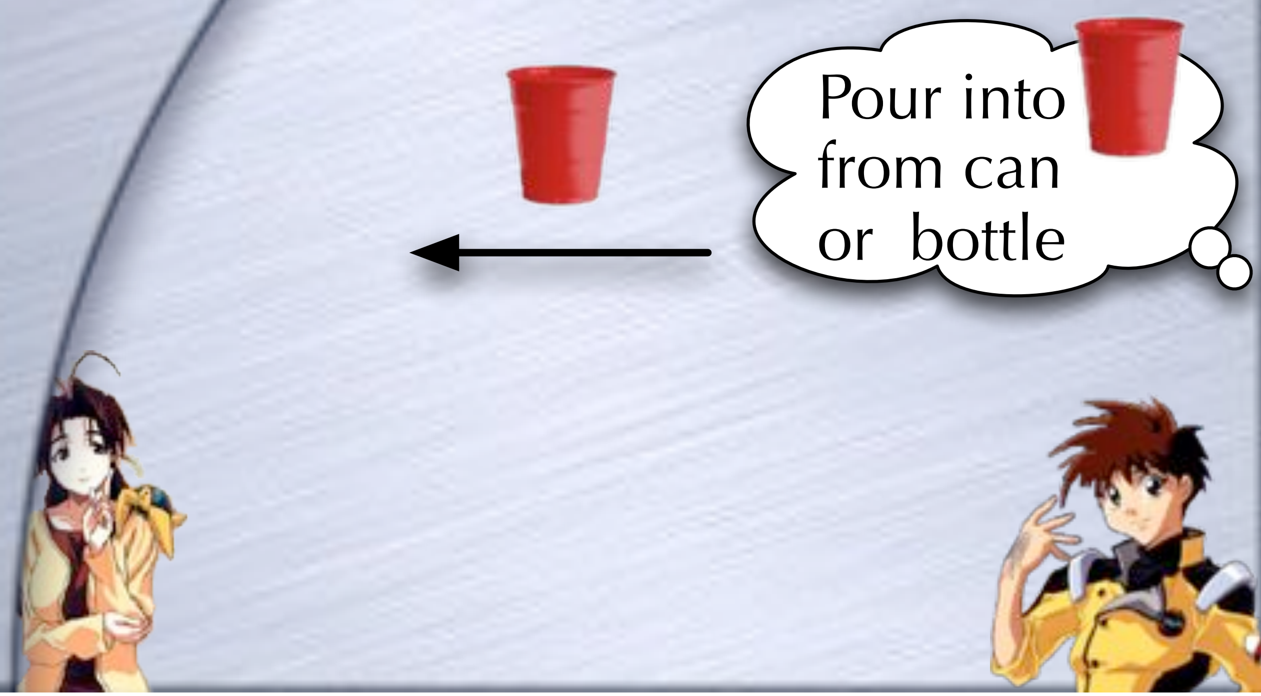

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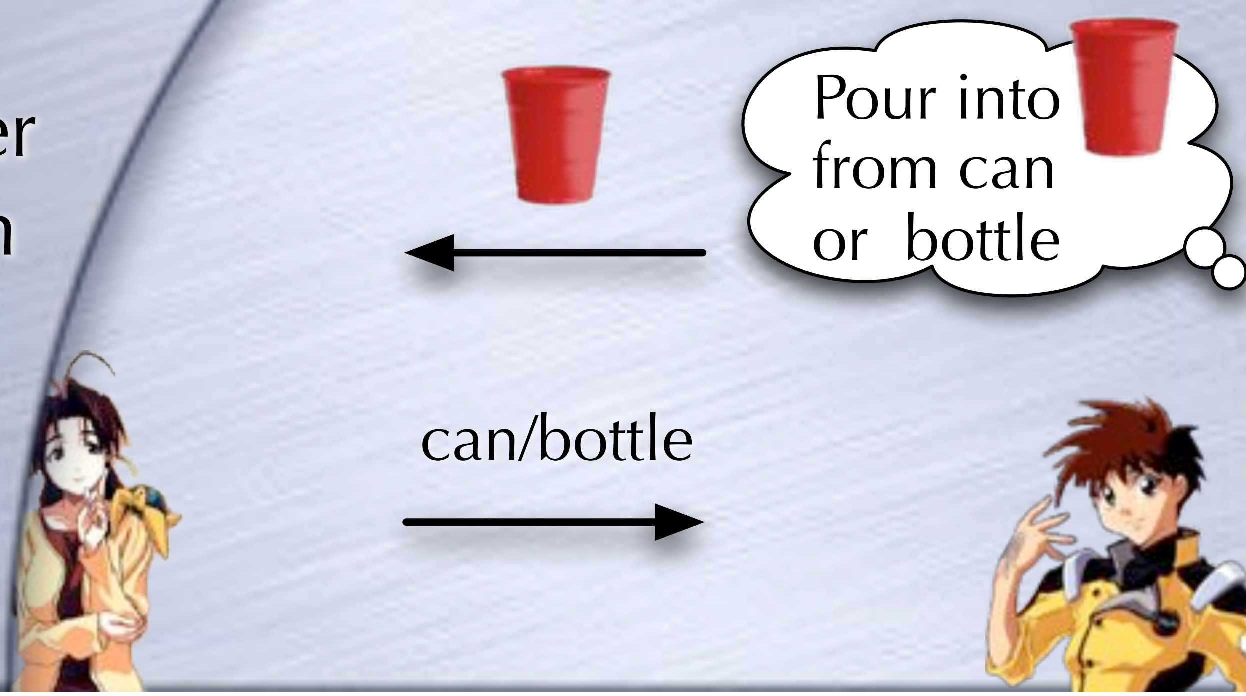

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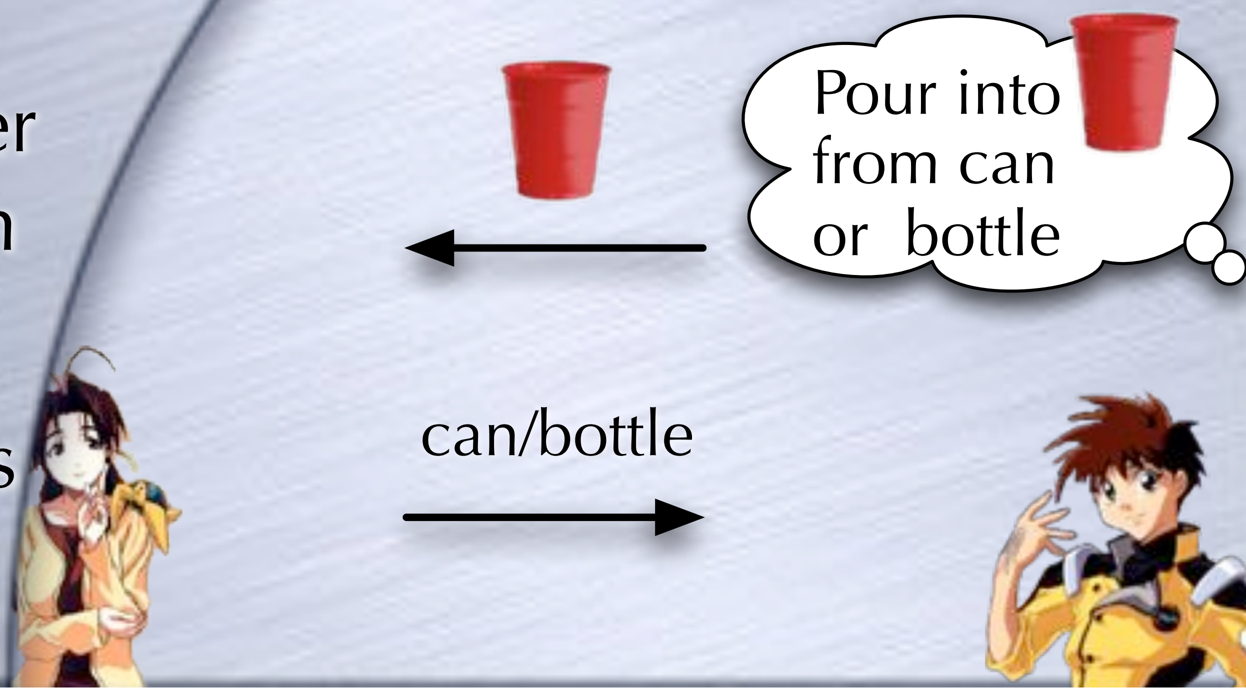

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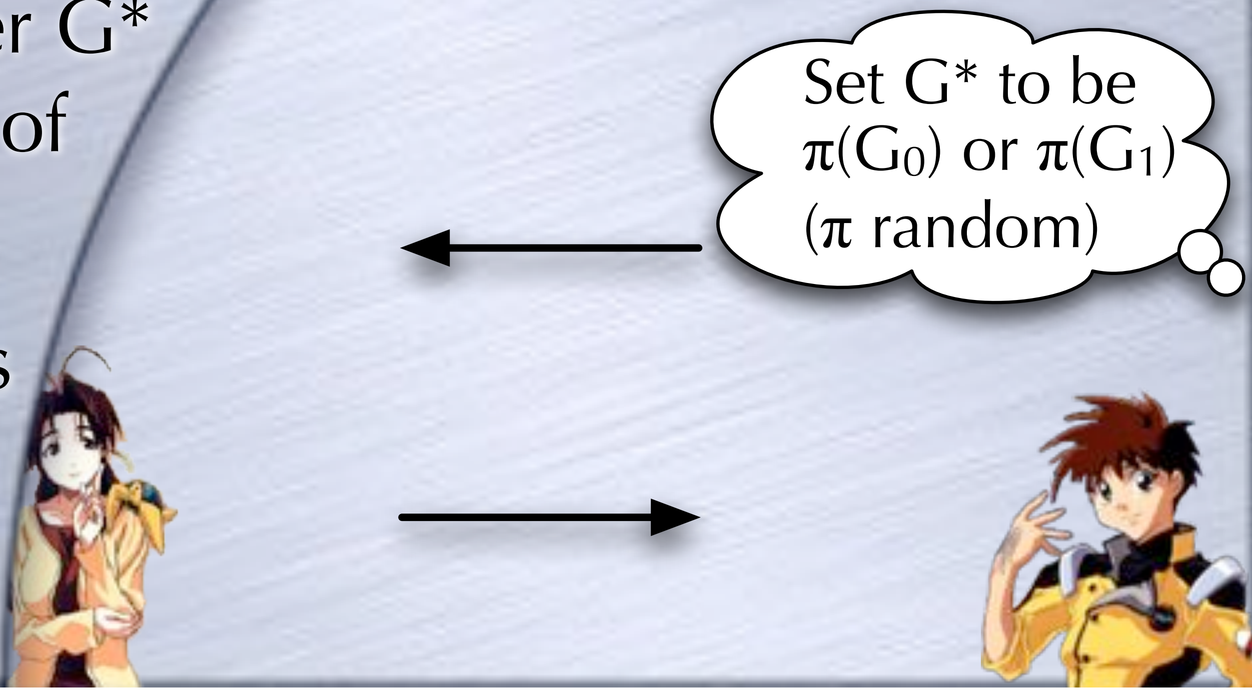

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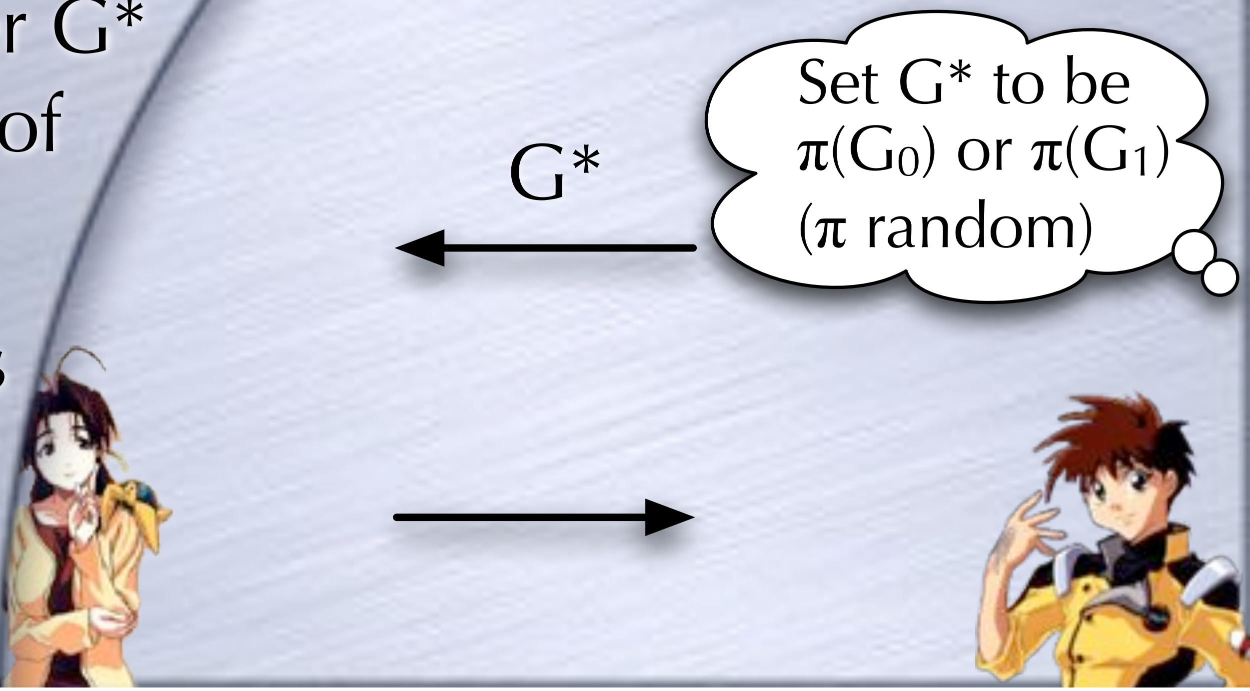

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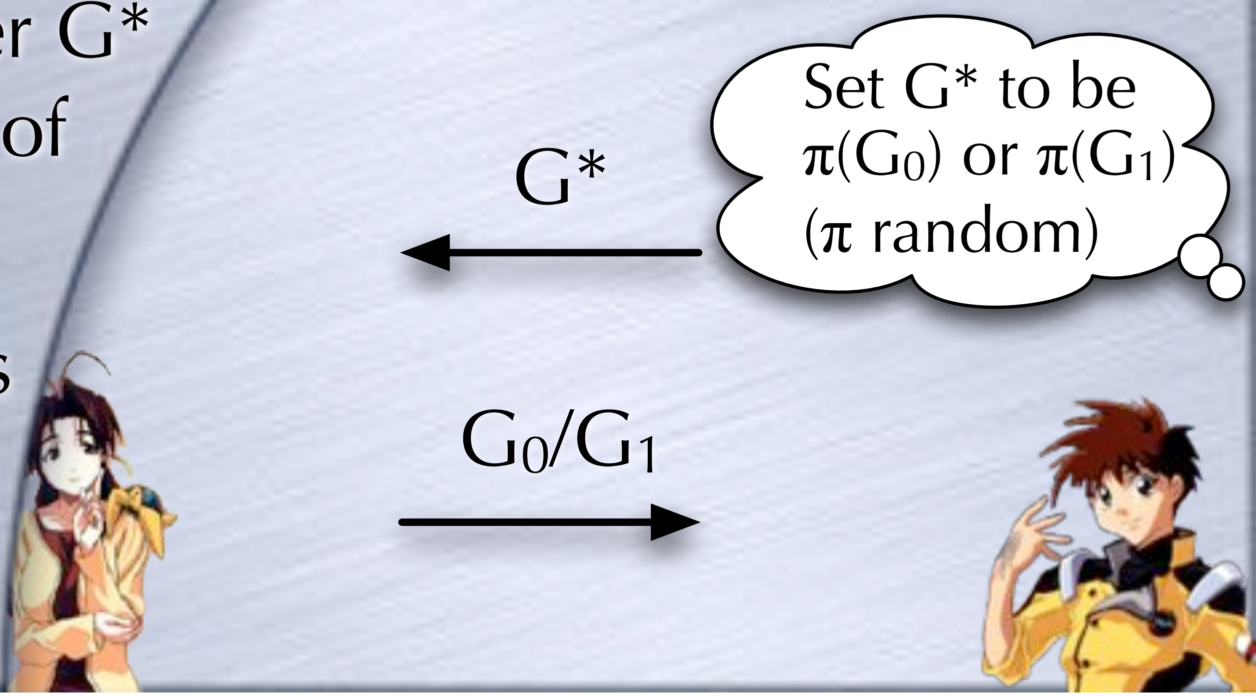
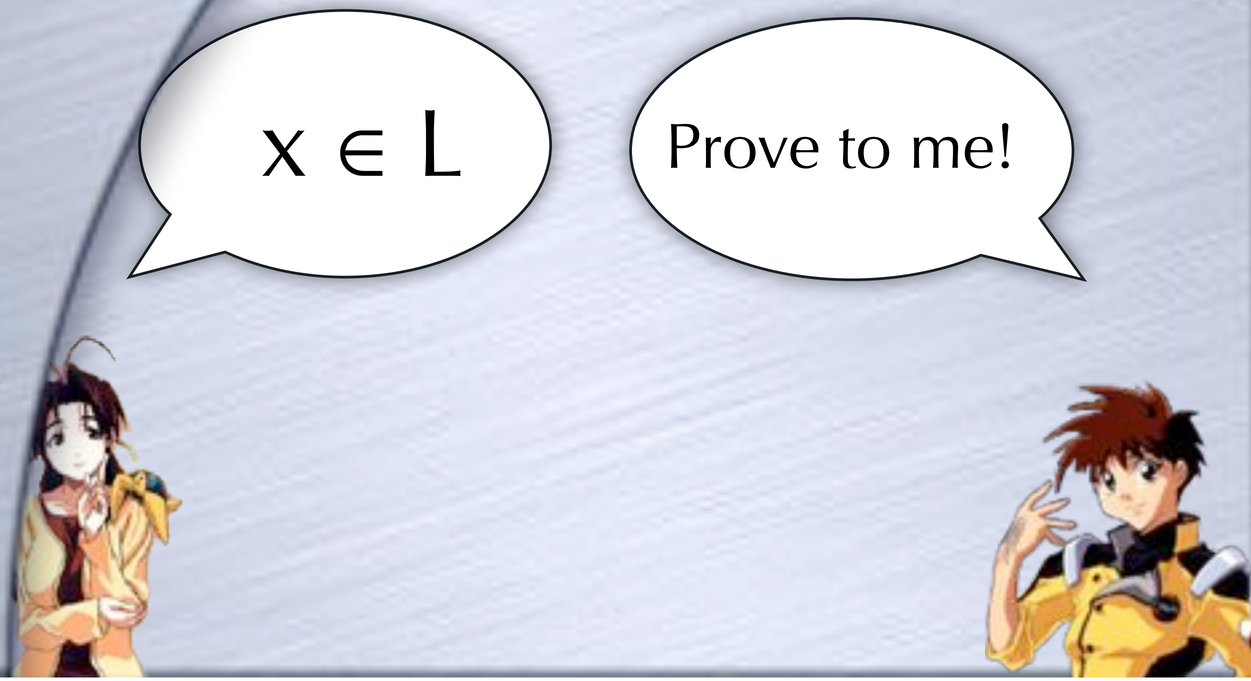


Proofs for NP languages



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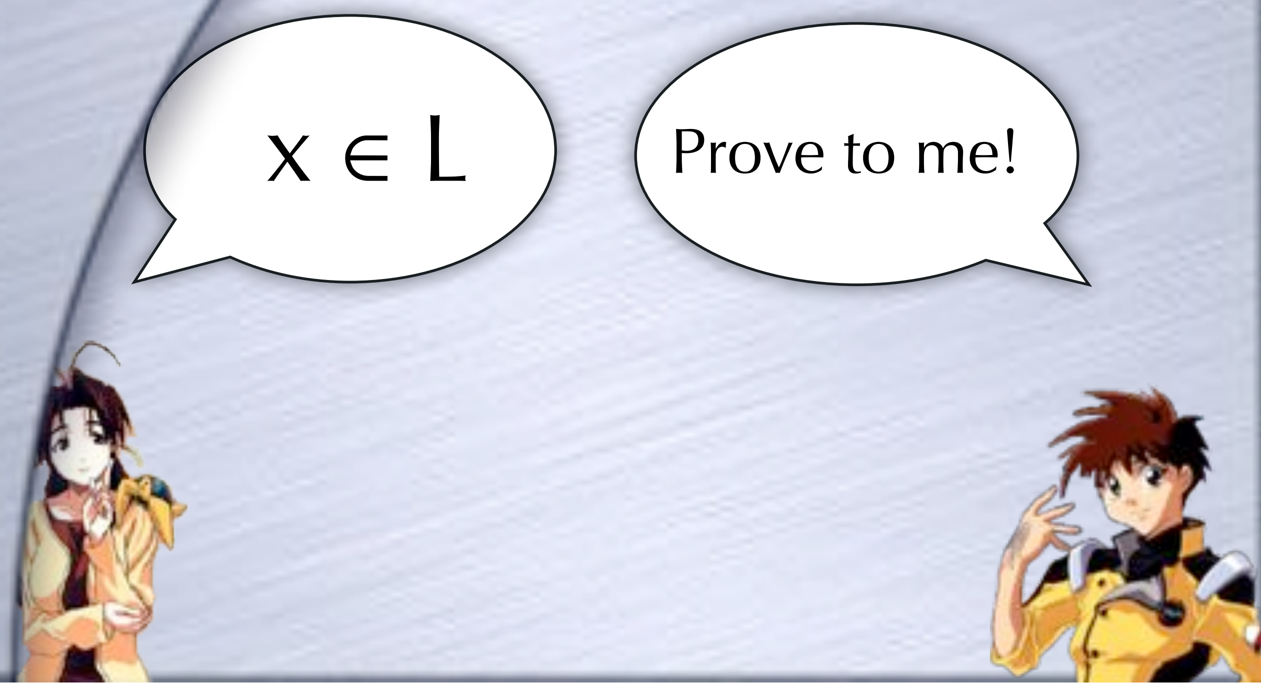

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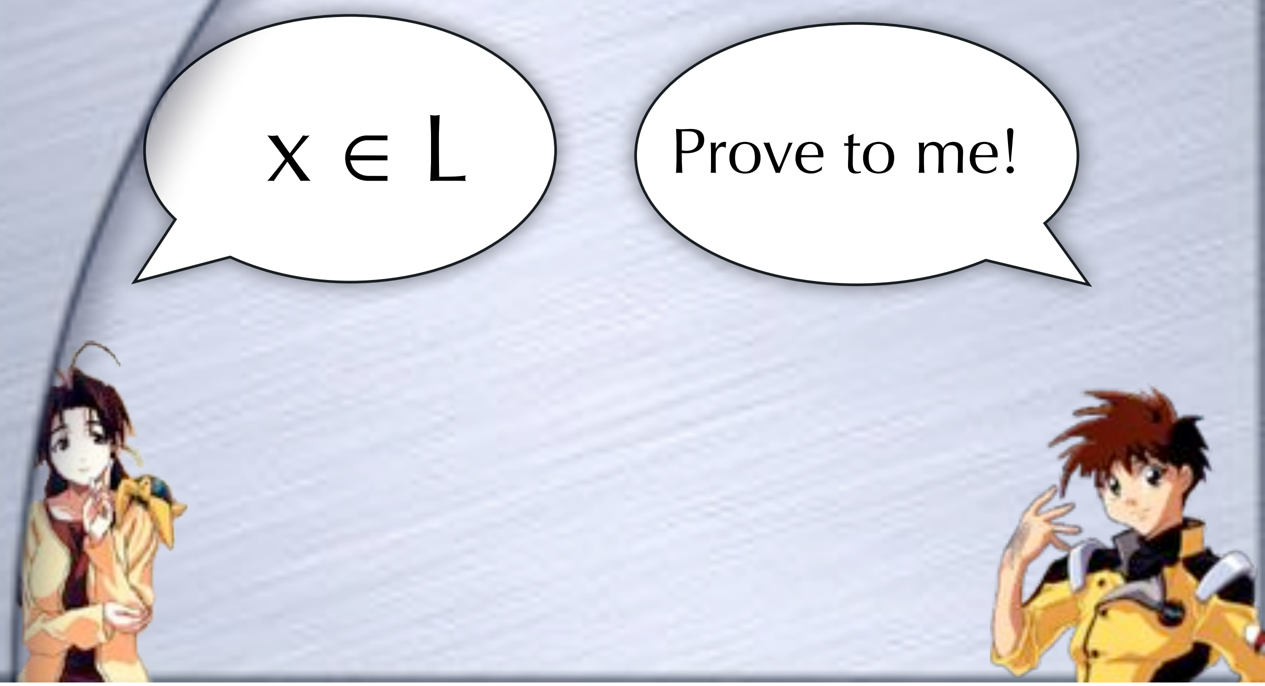

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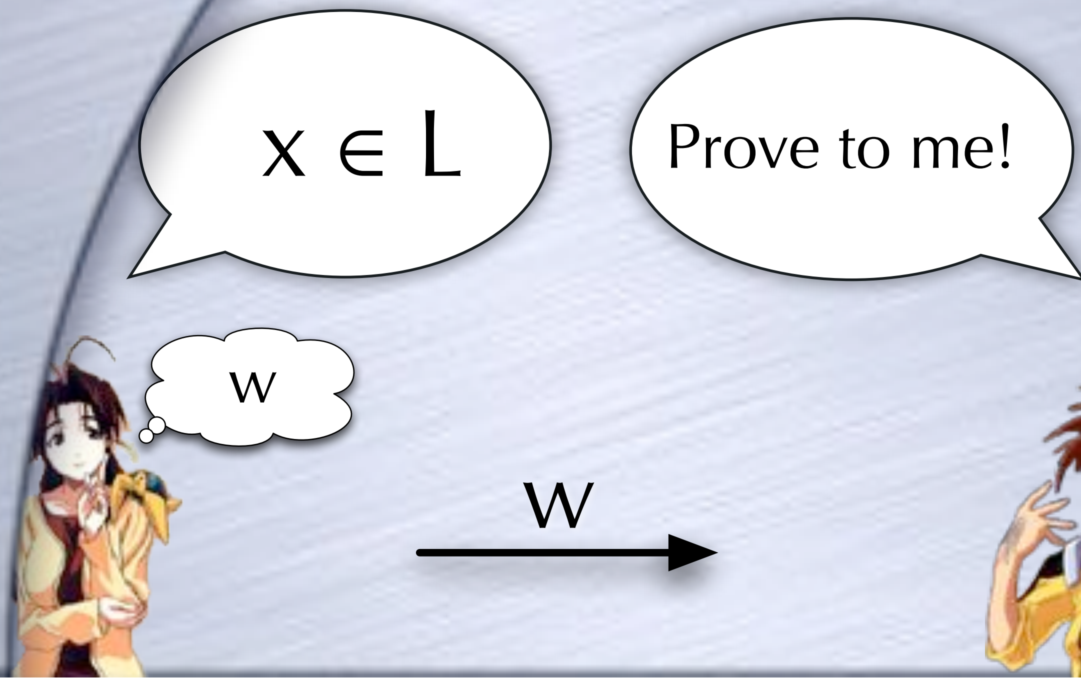

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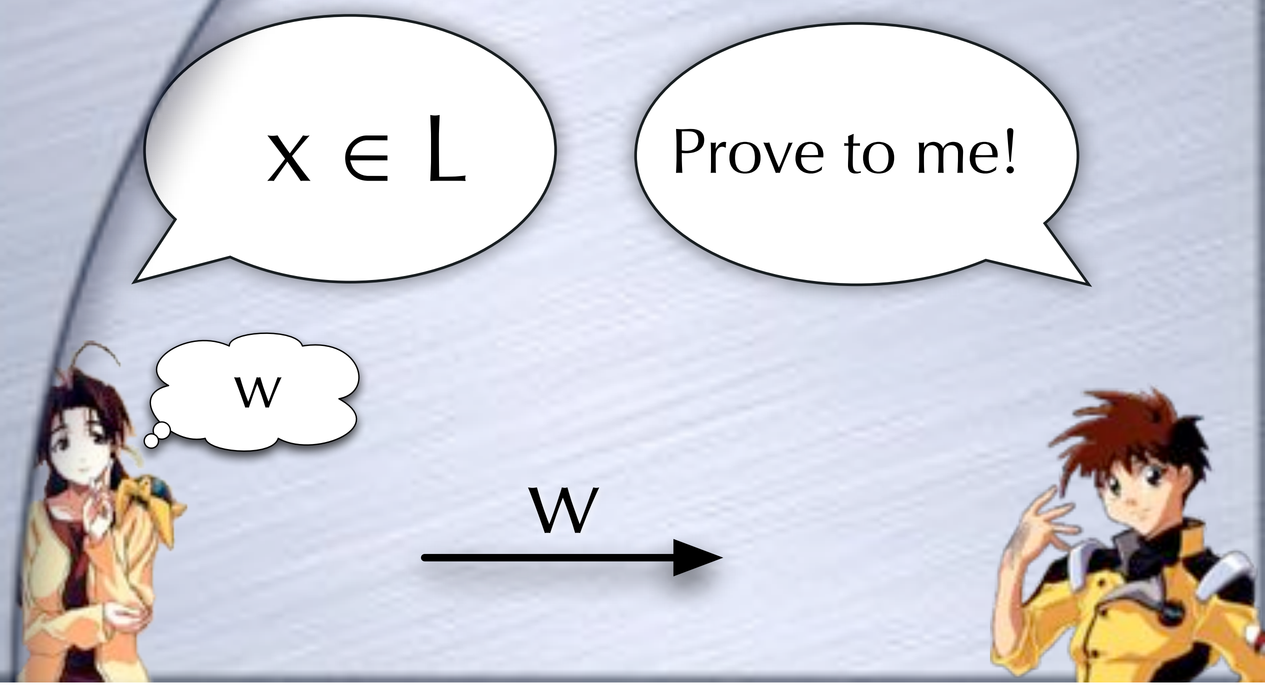

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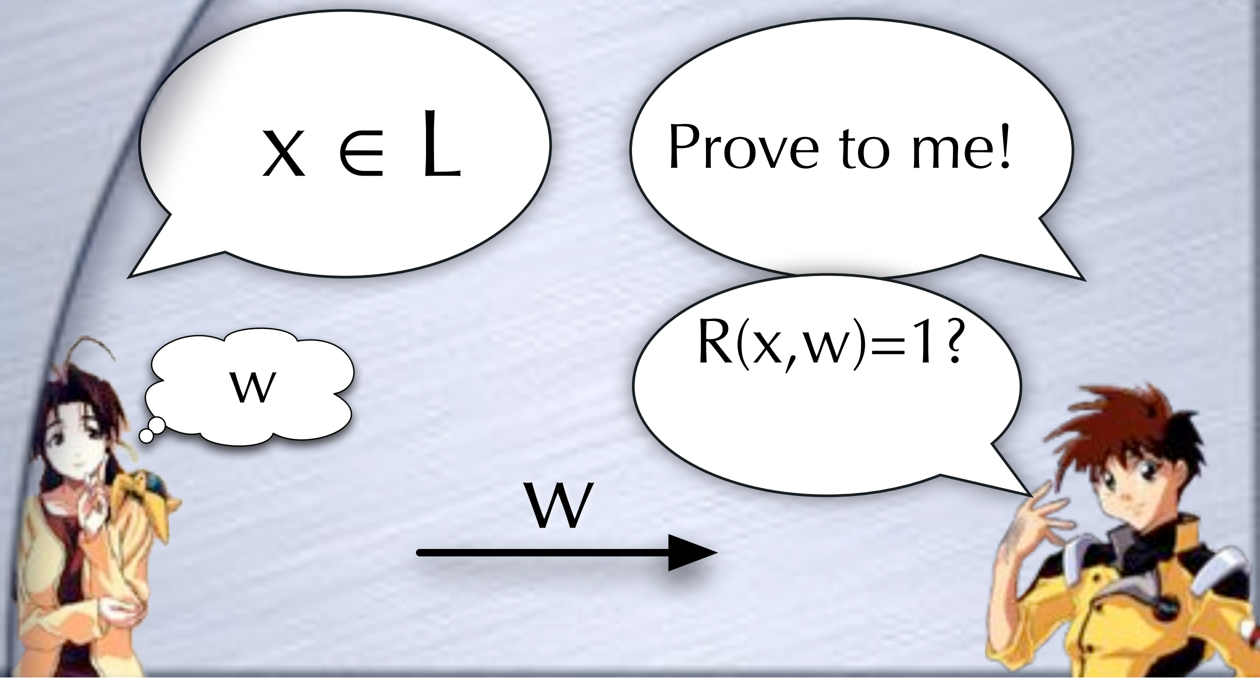

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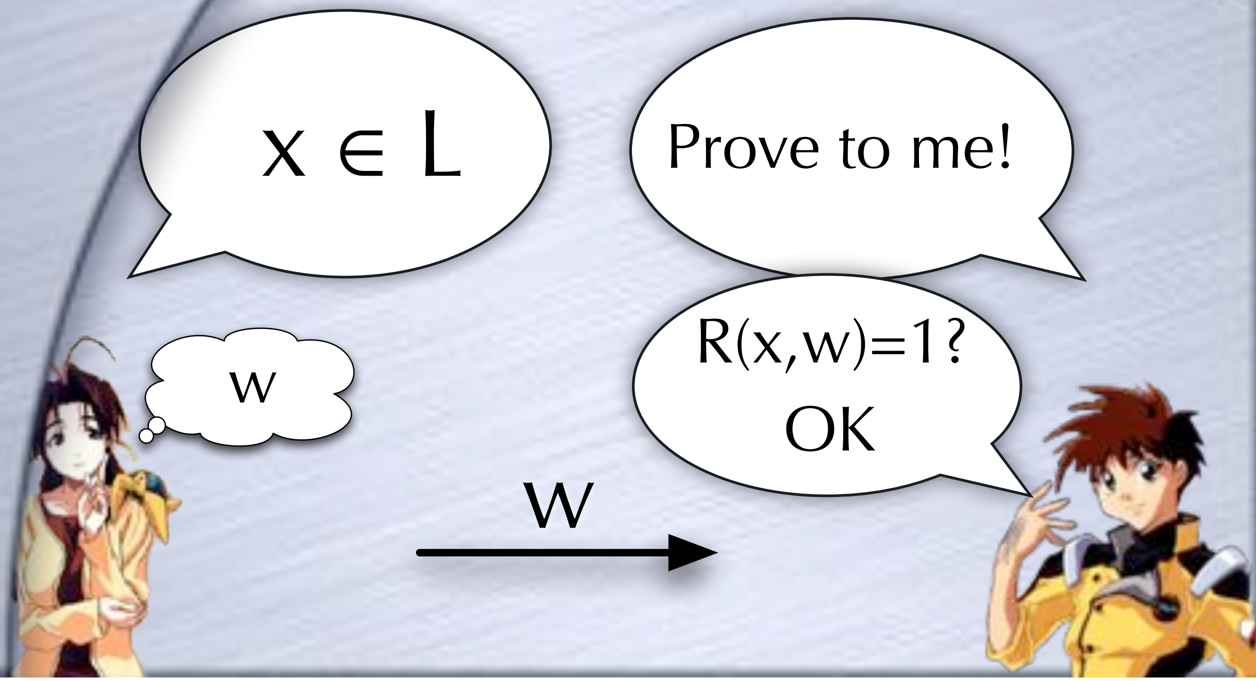

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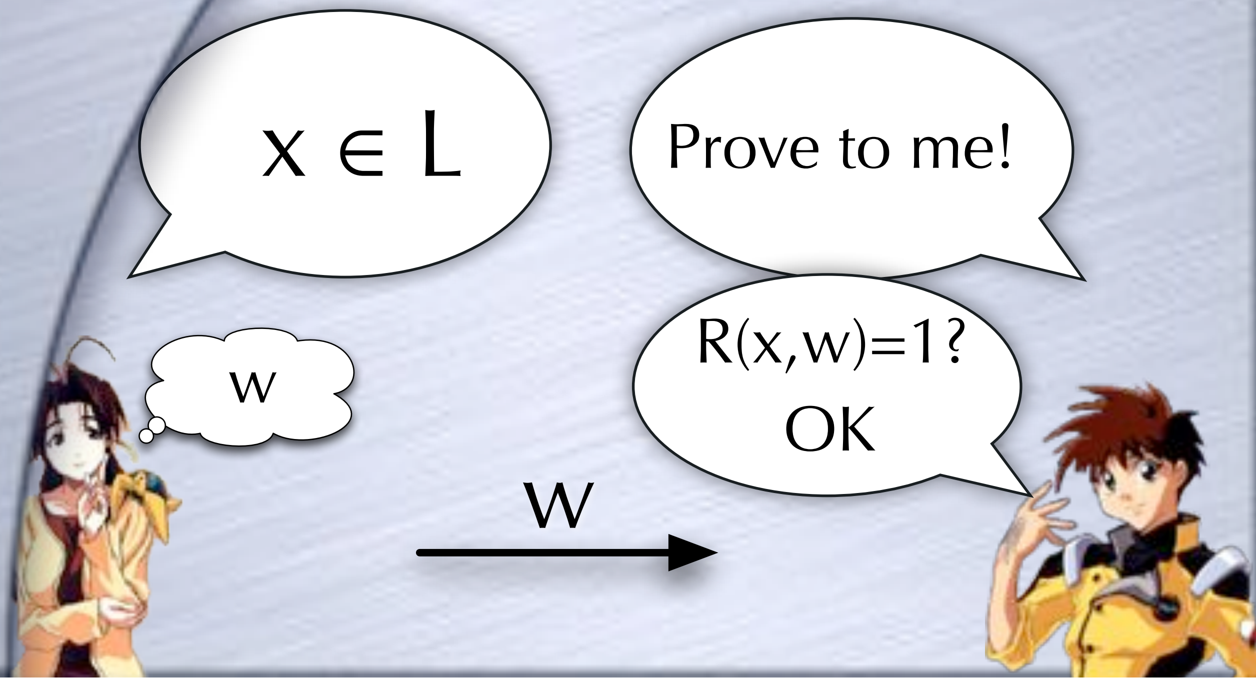

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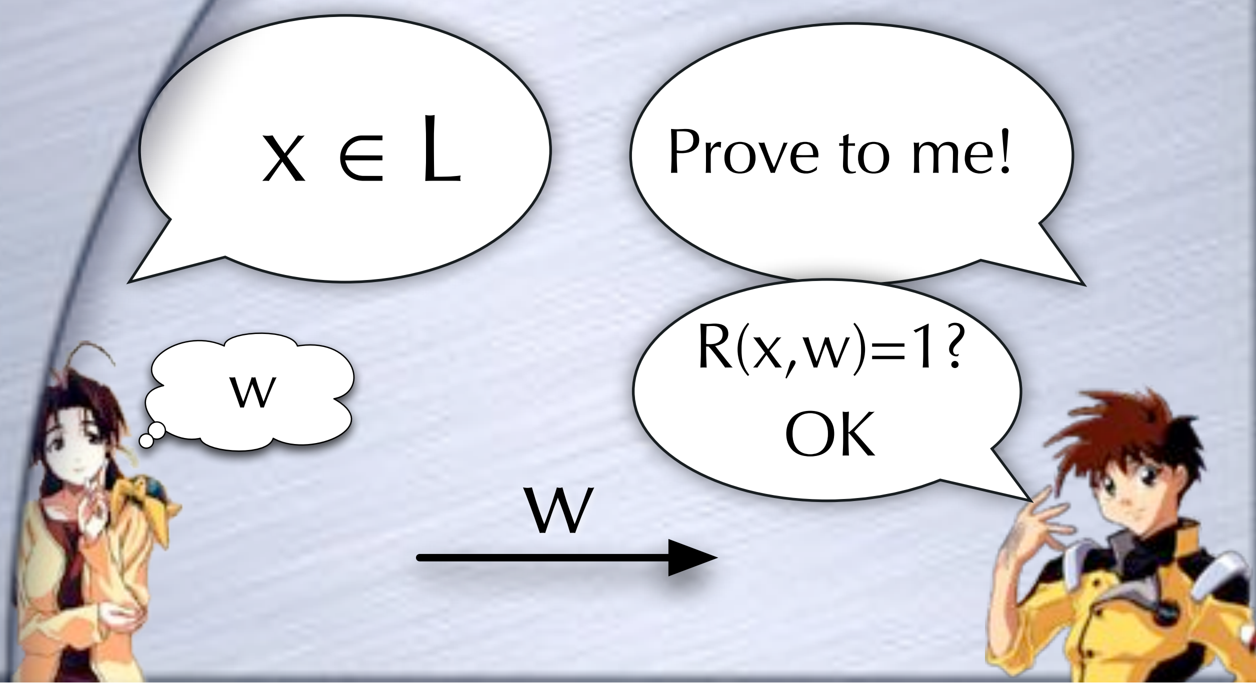
- *What if prover doesn't want to reveal w?*



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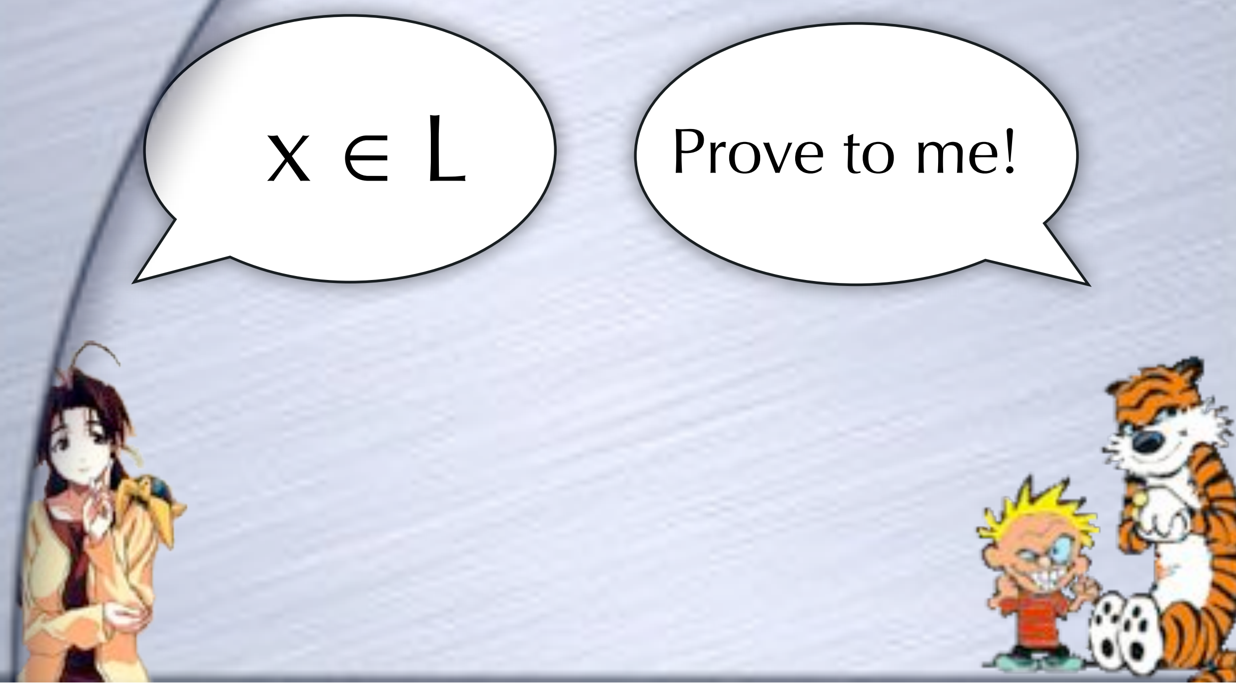

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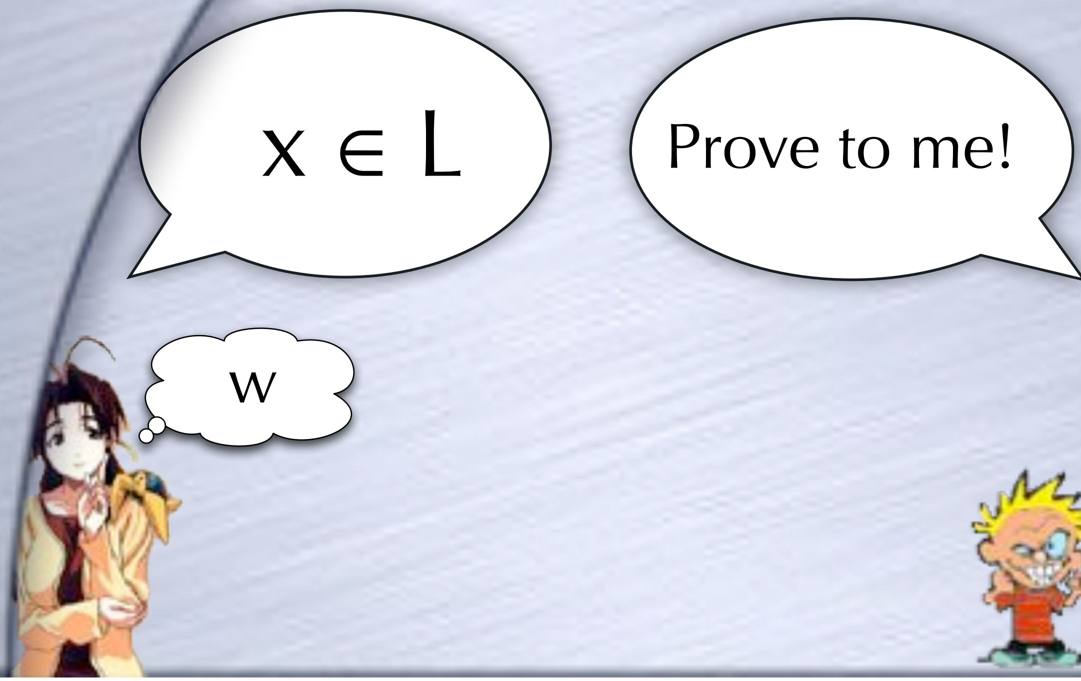

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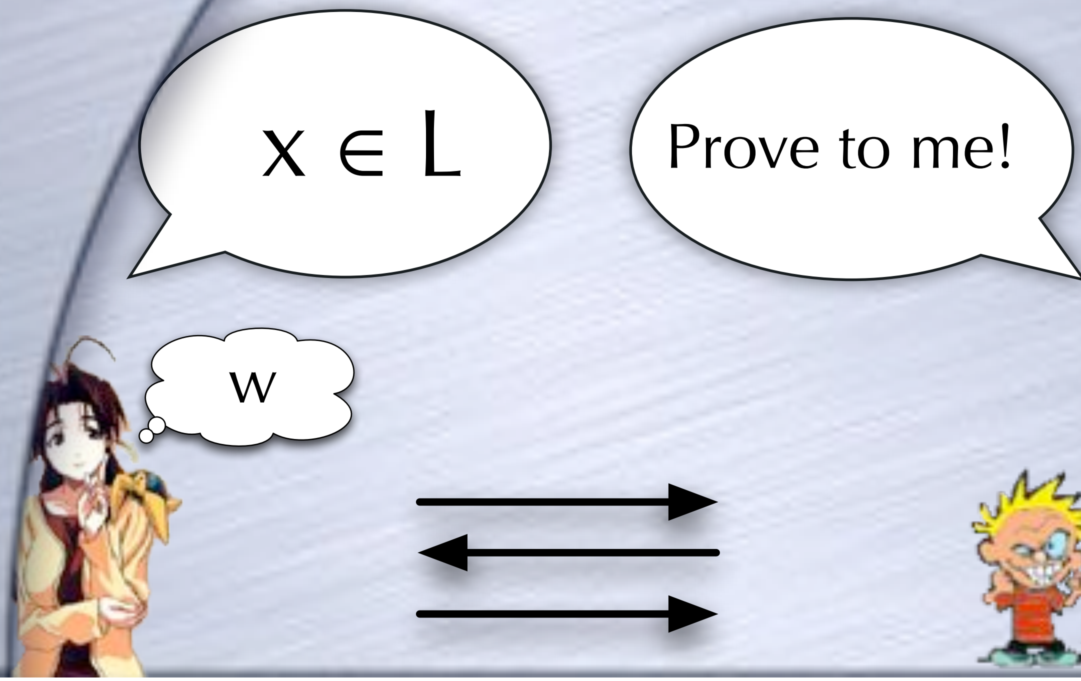

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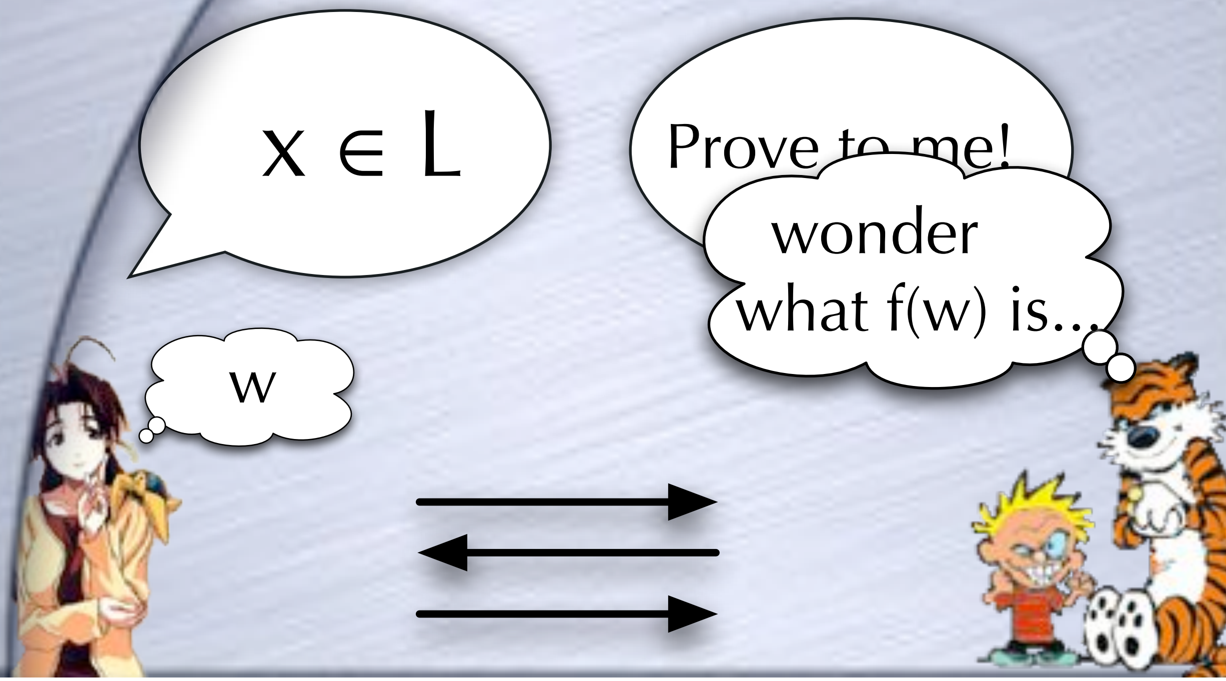

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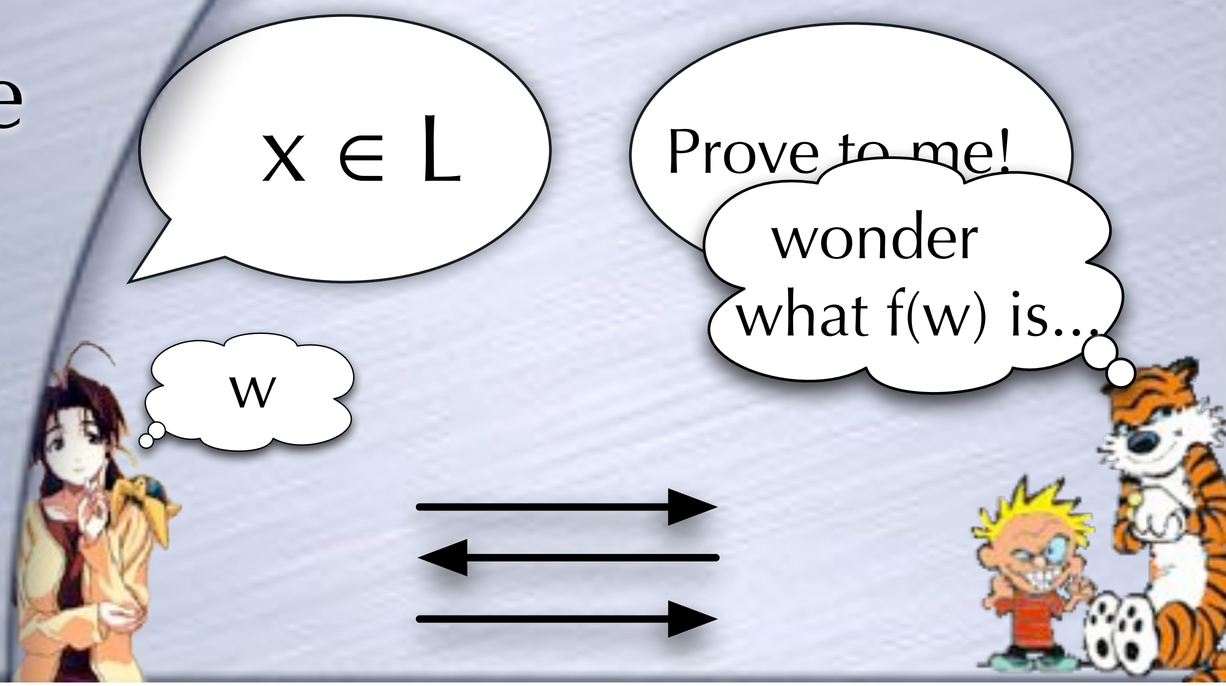

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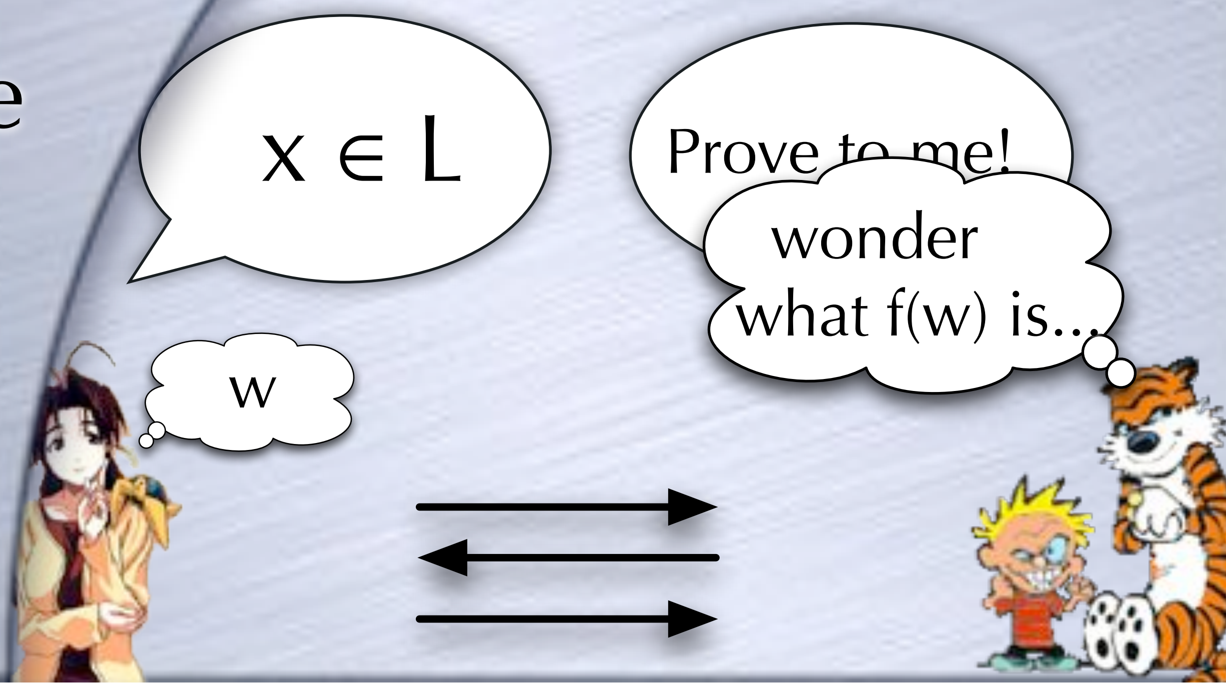
- How to formalize this?
  - Simulation!



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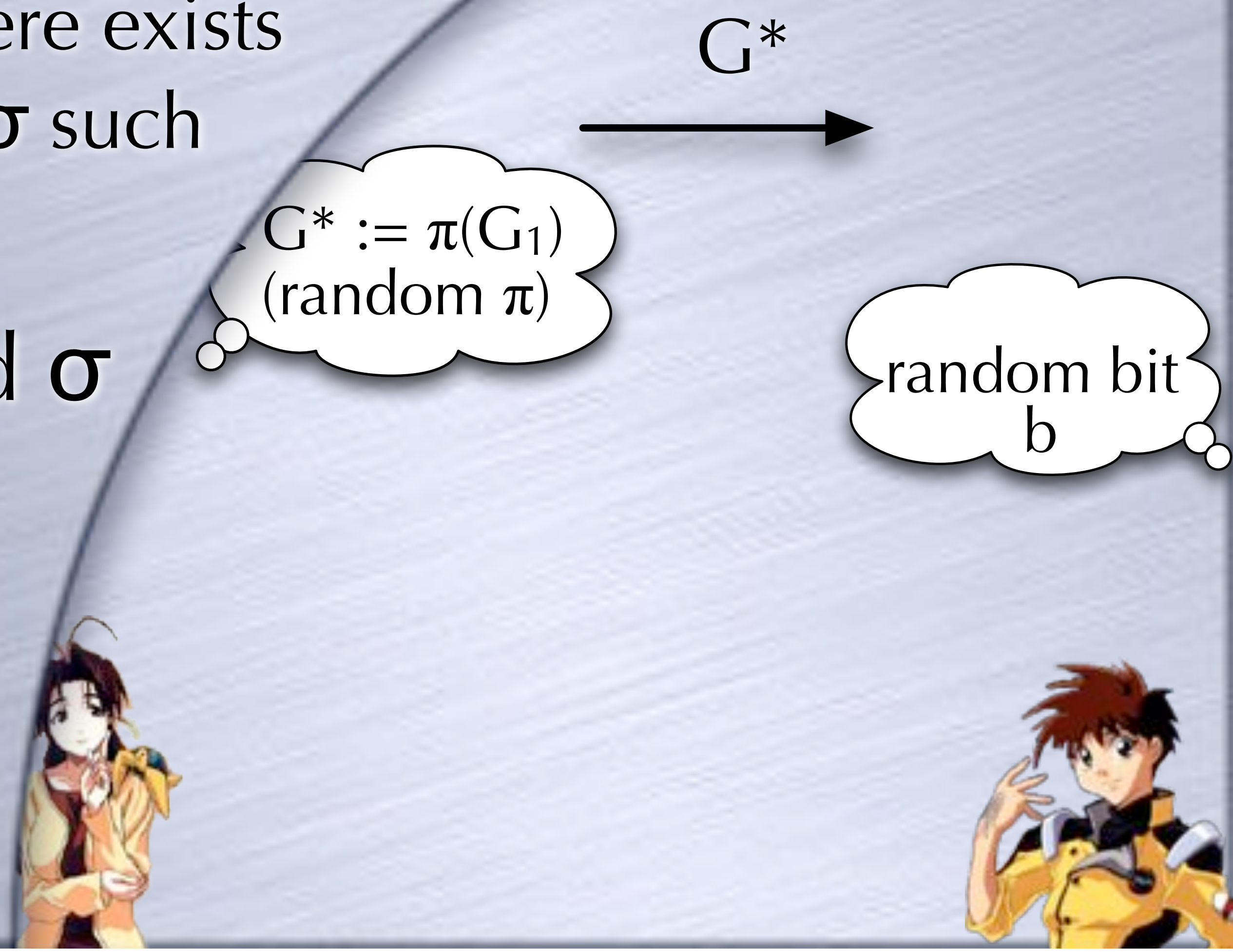

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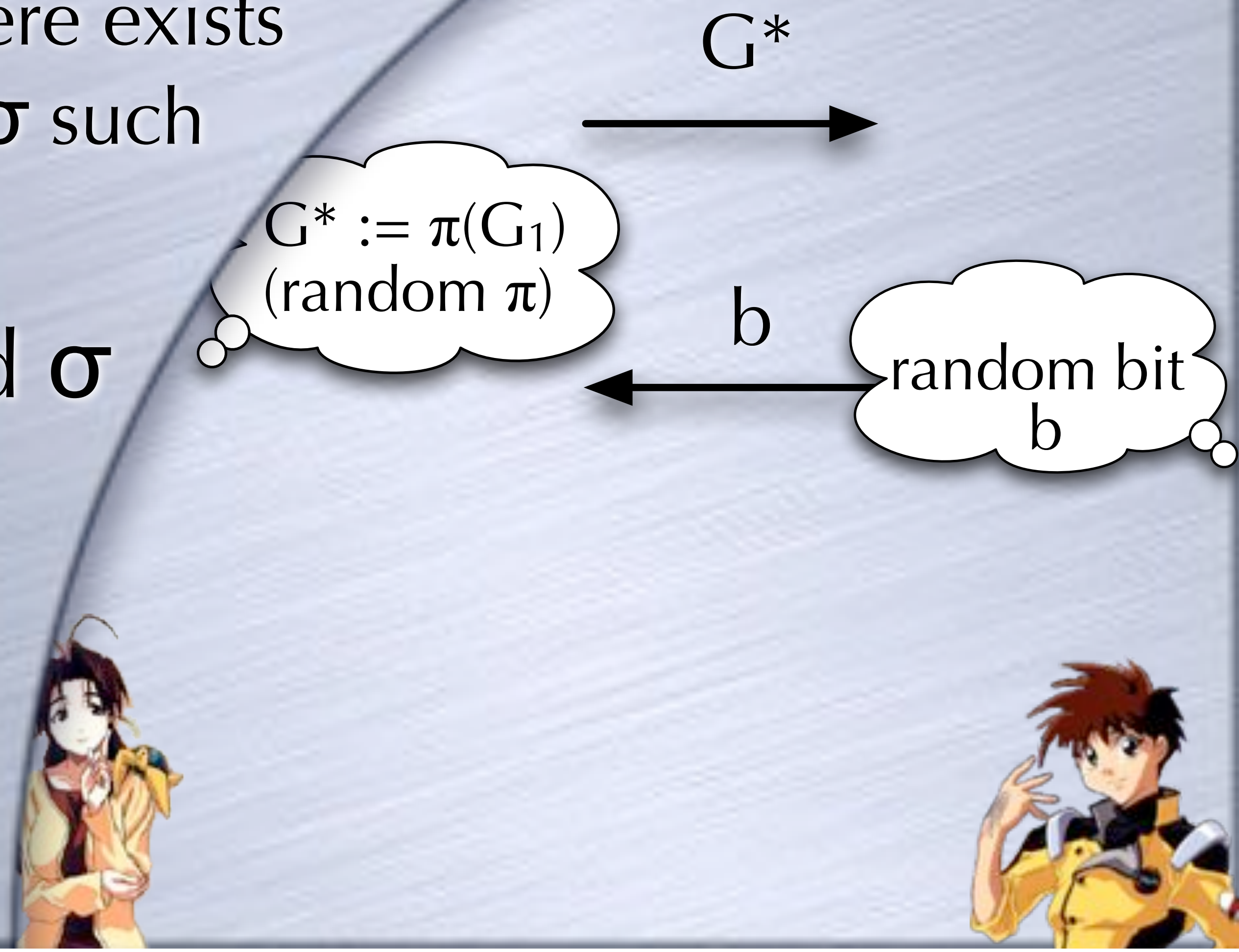

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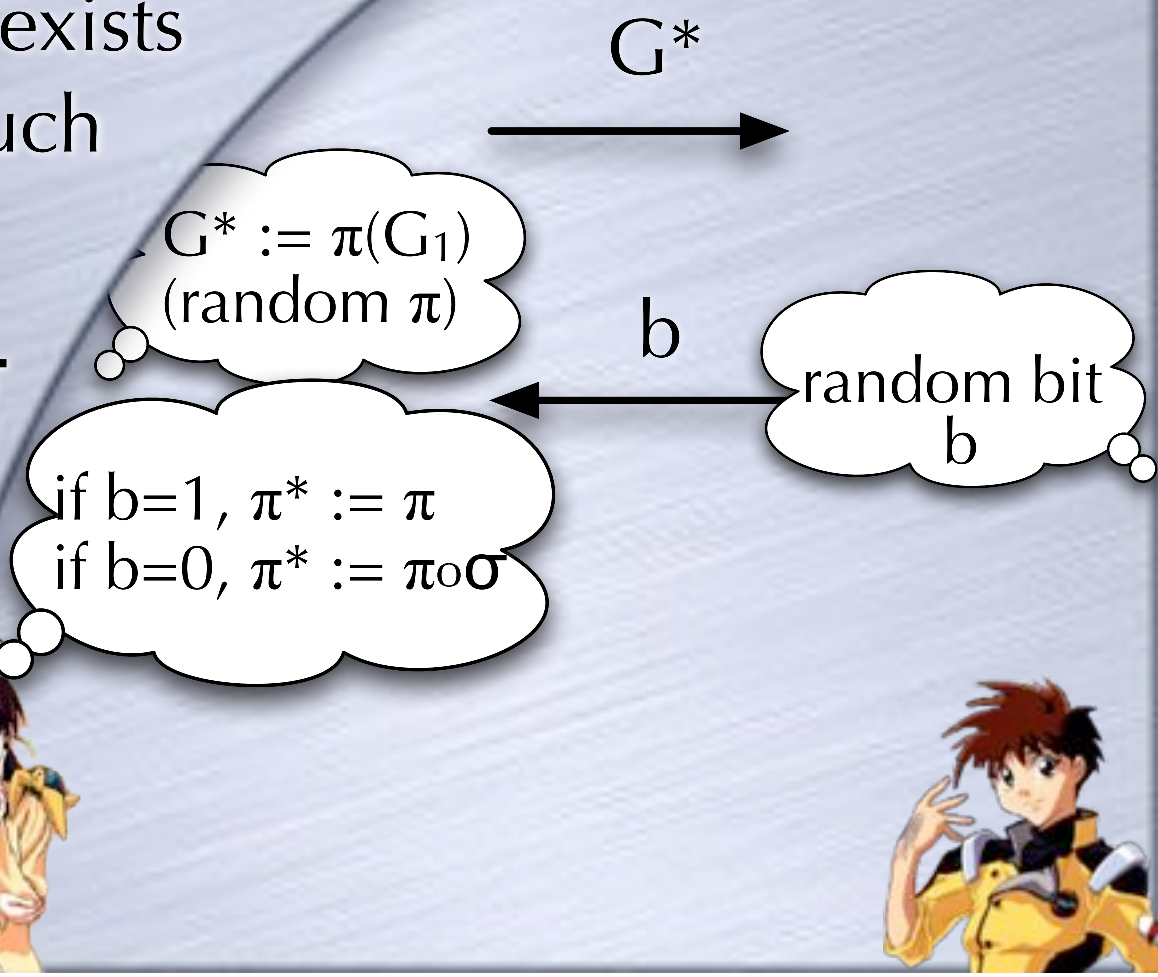

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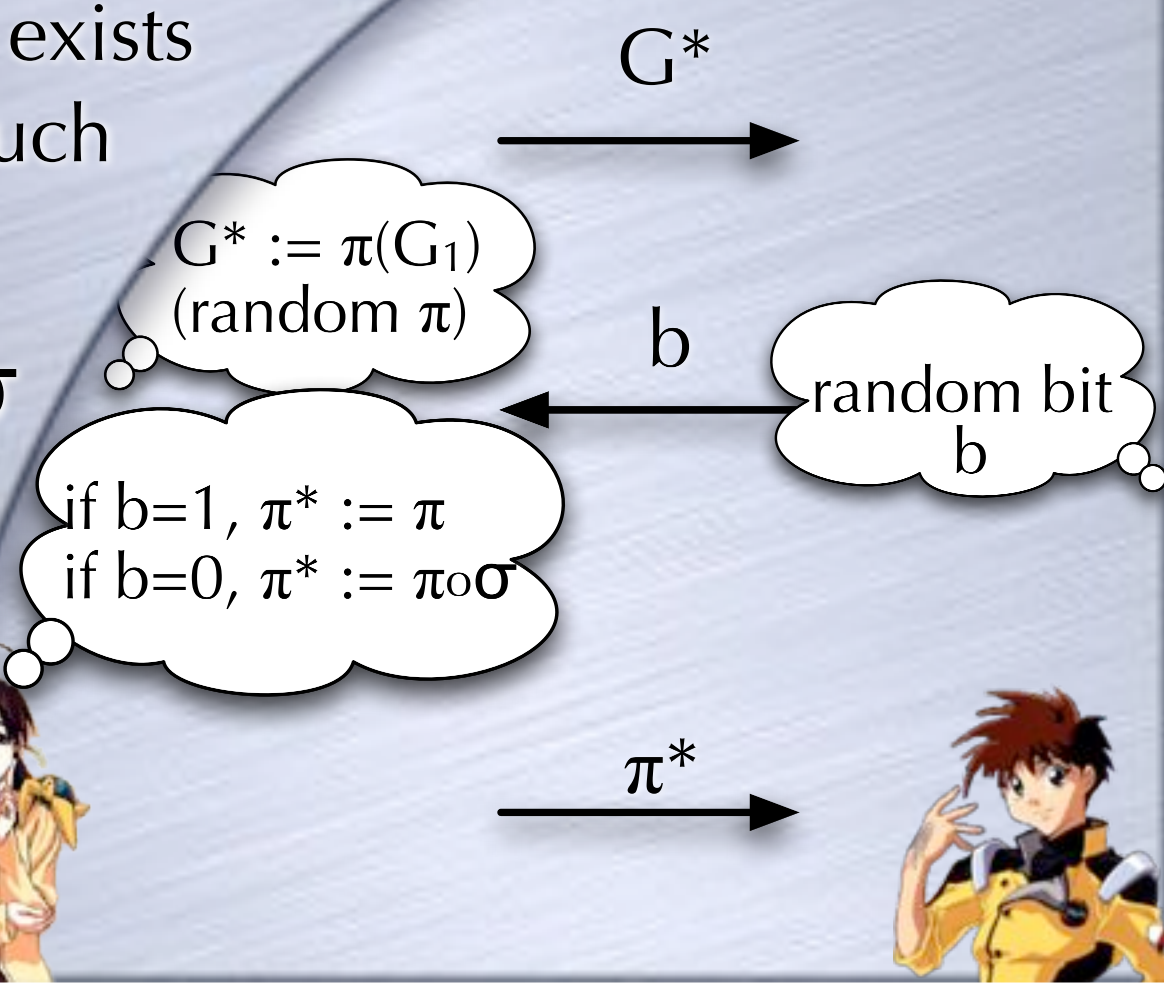

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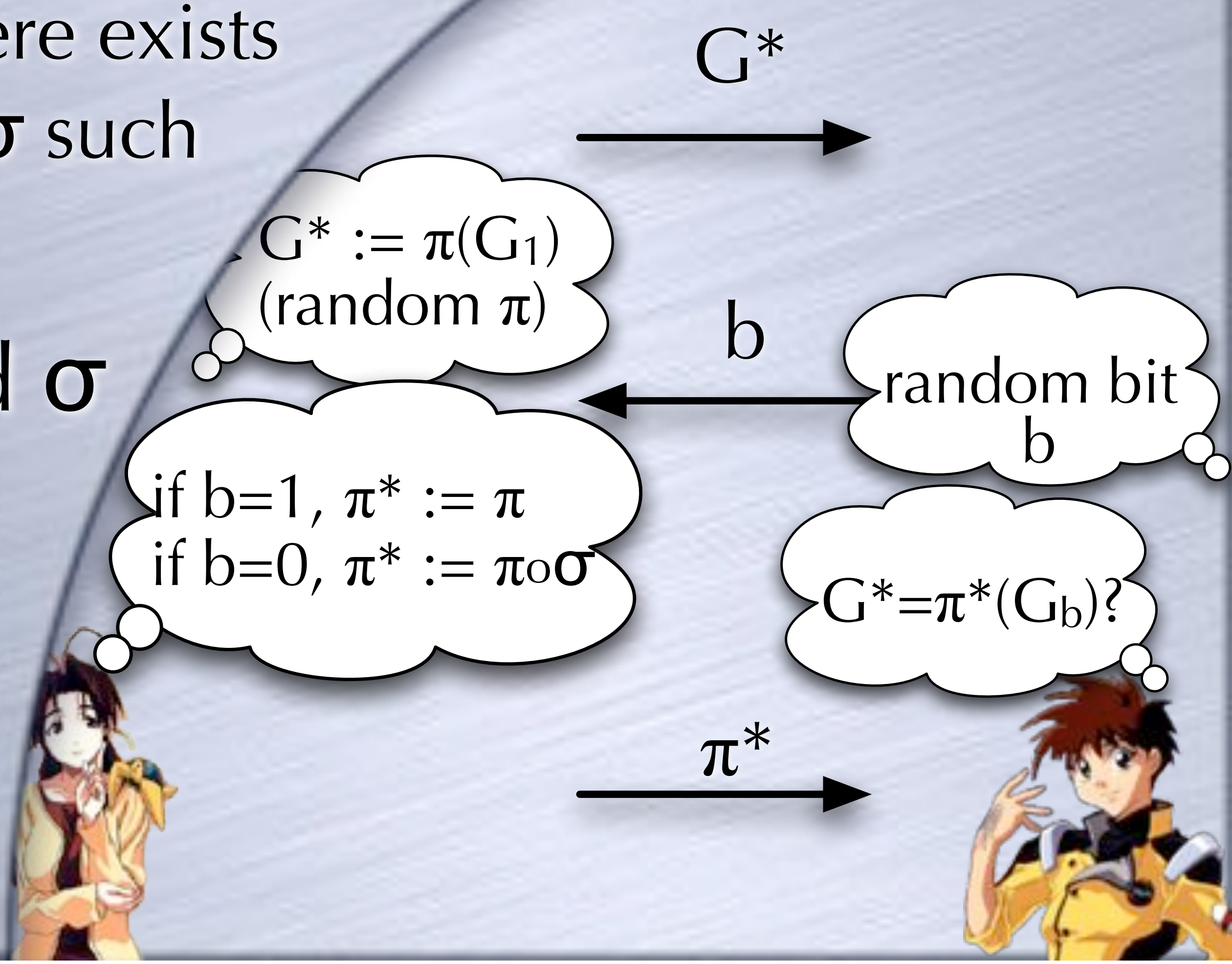

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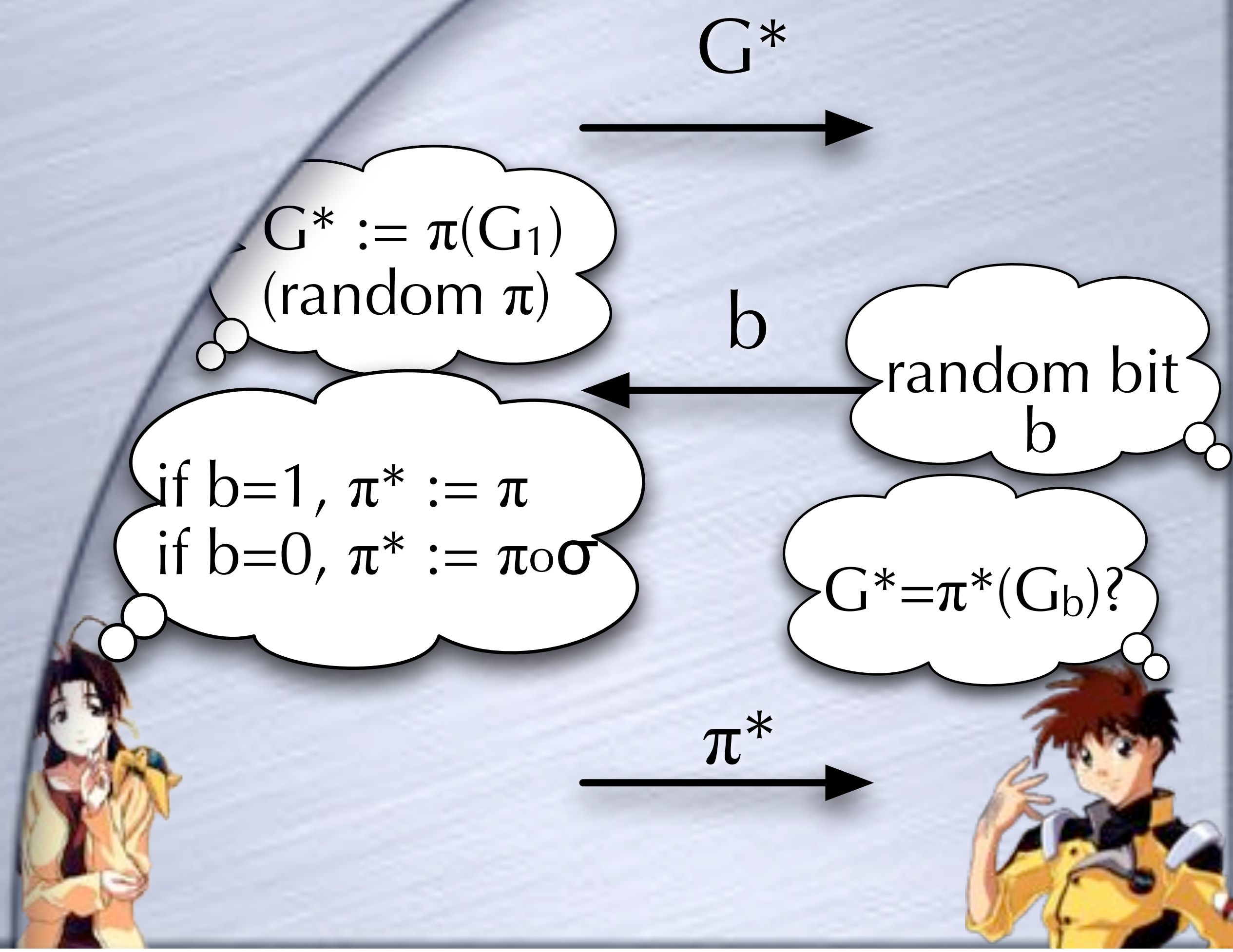

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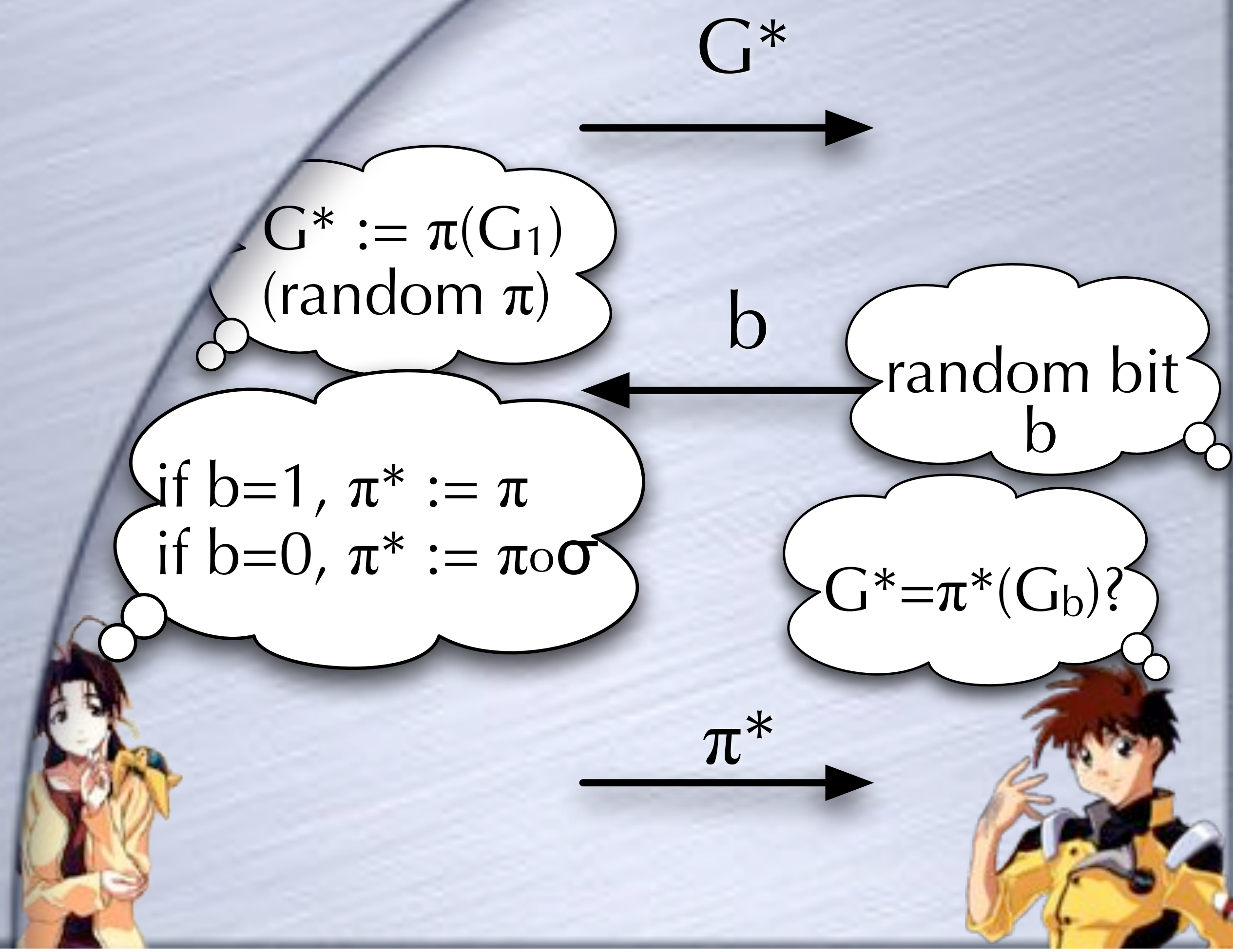

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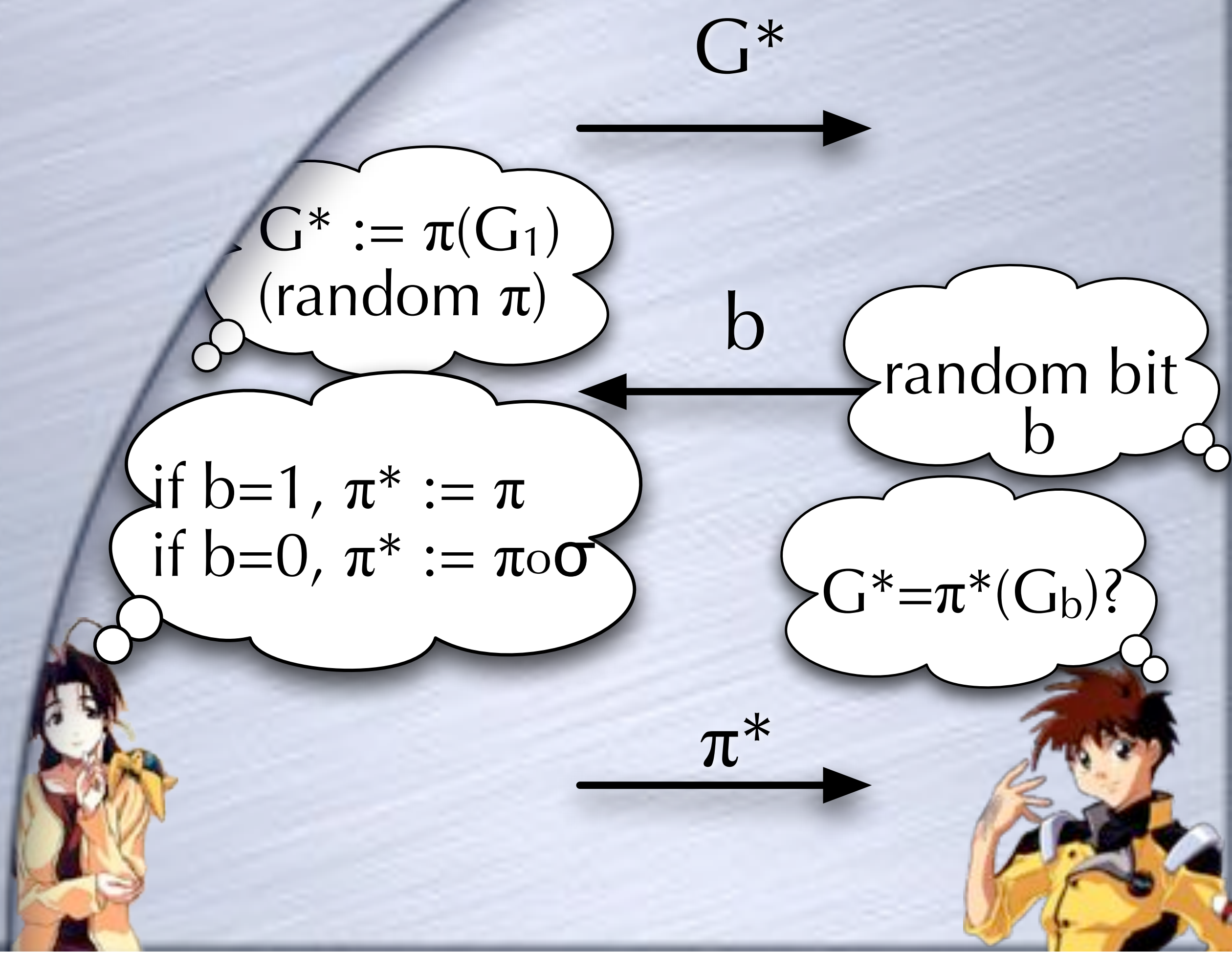

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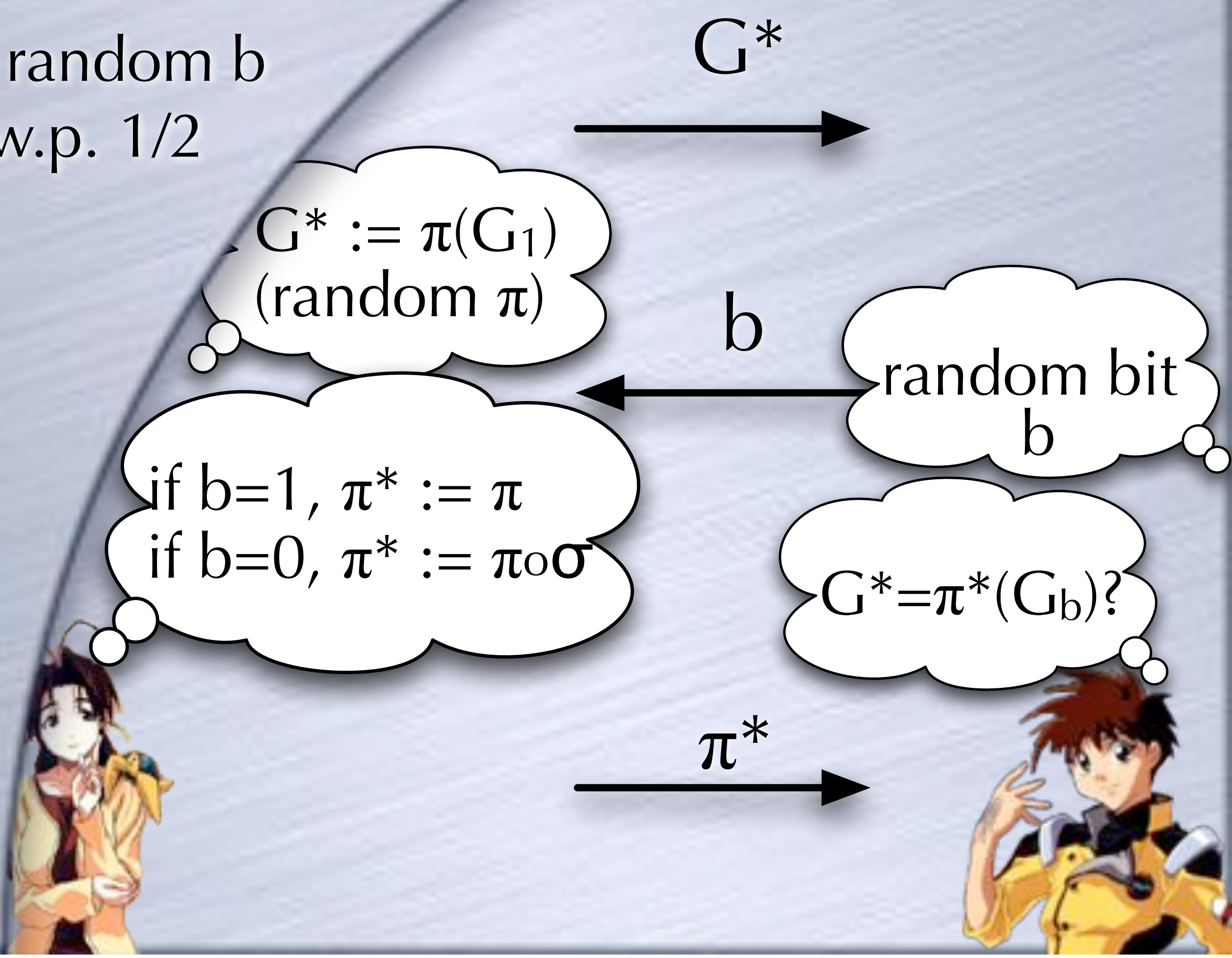

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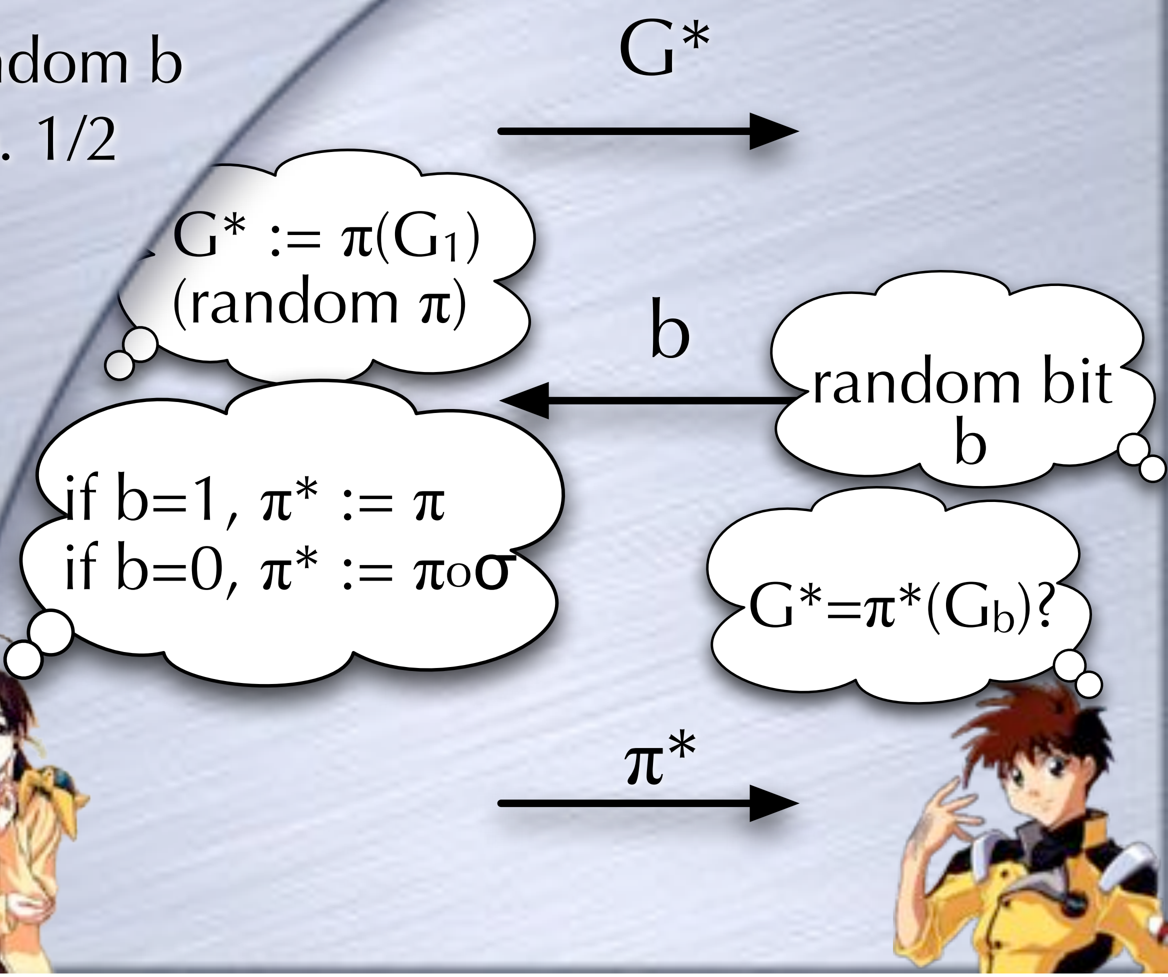

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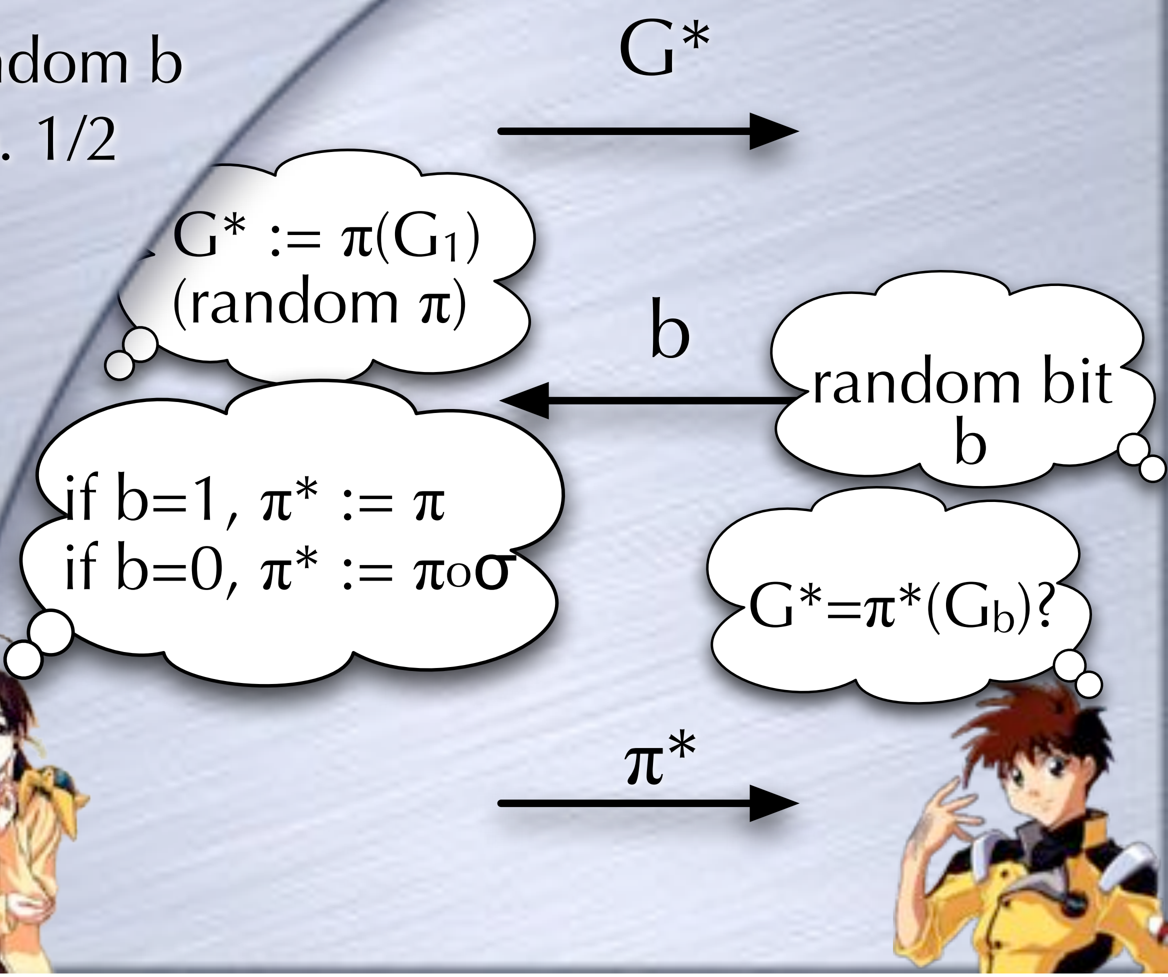

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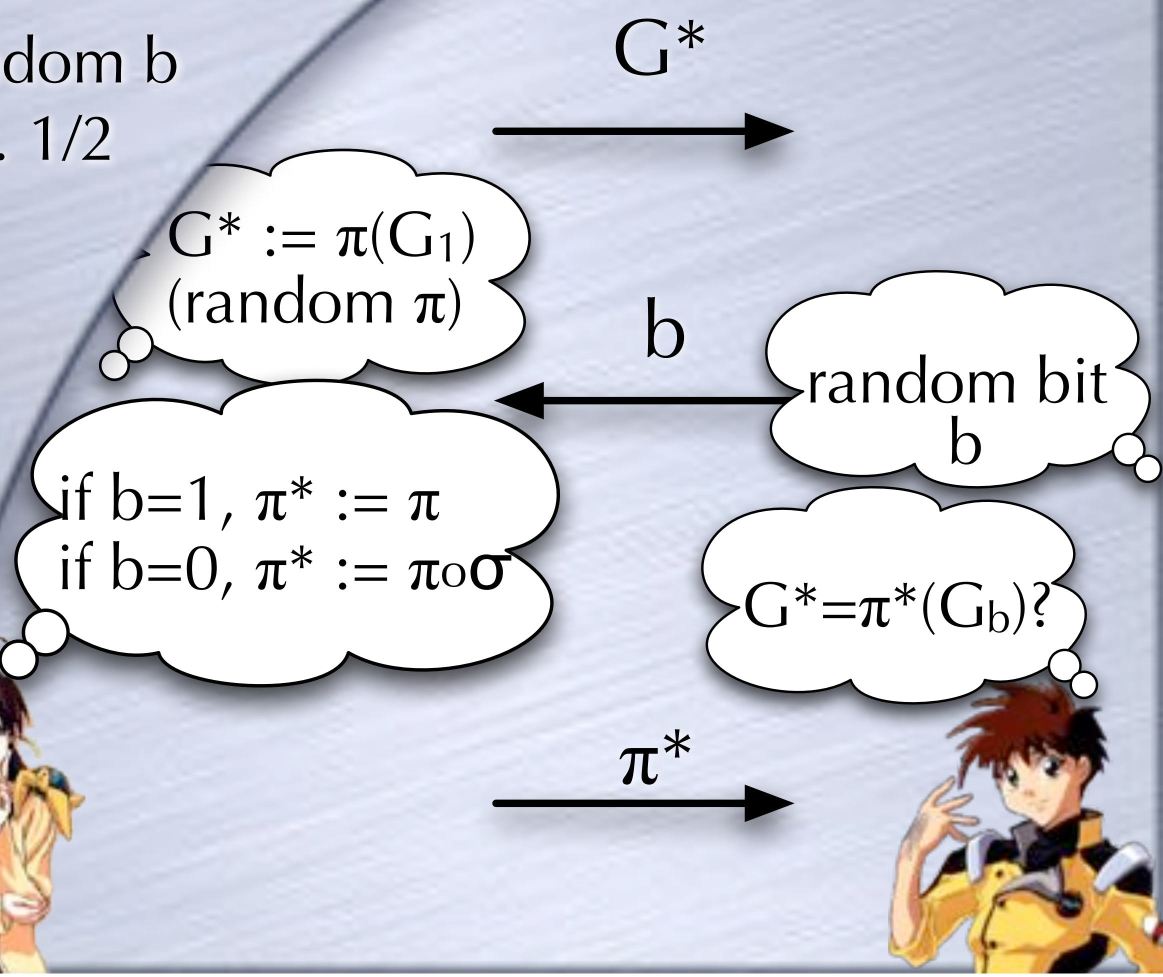
  - Which he could have generated by himself (whether $G_0 \sim G_1$ or not)



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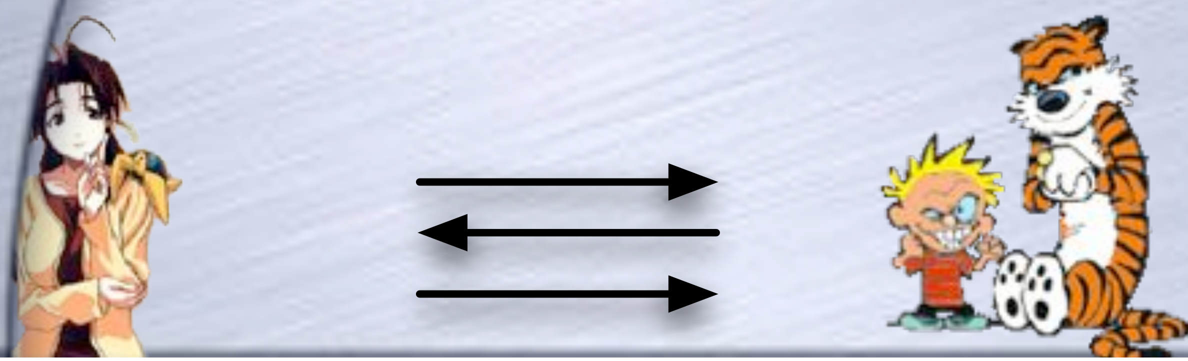

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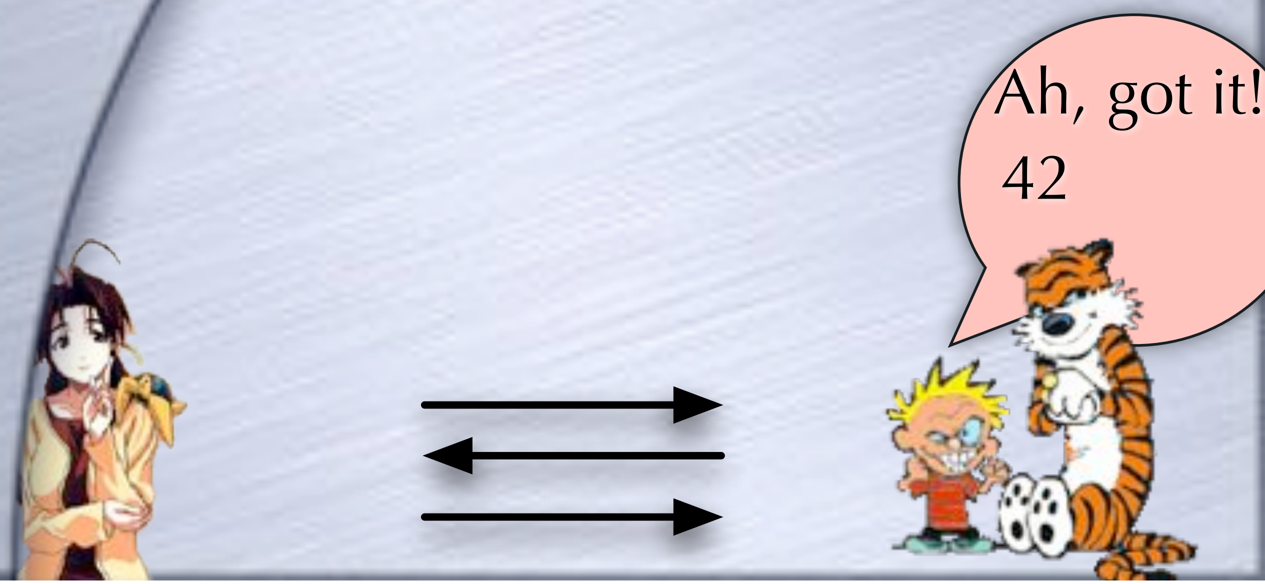

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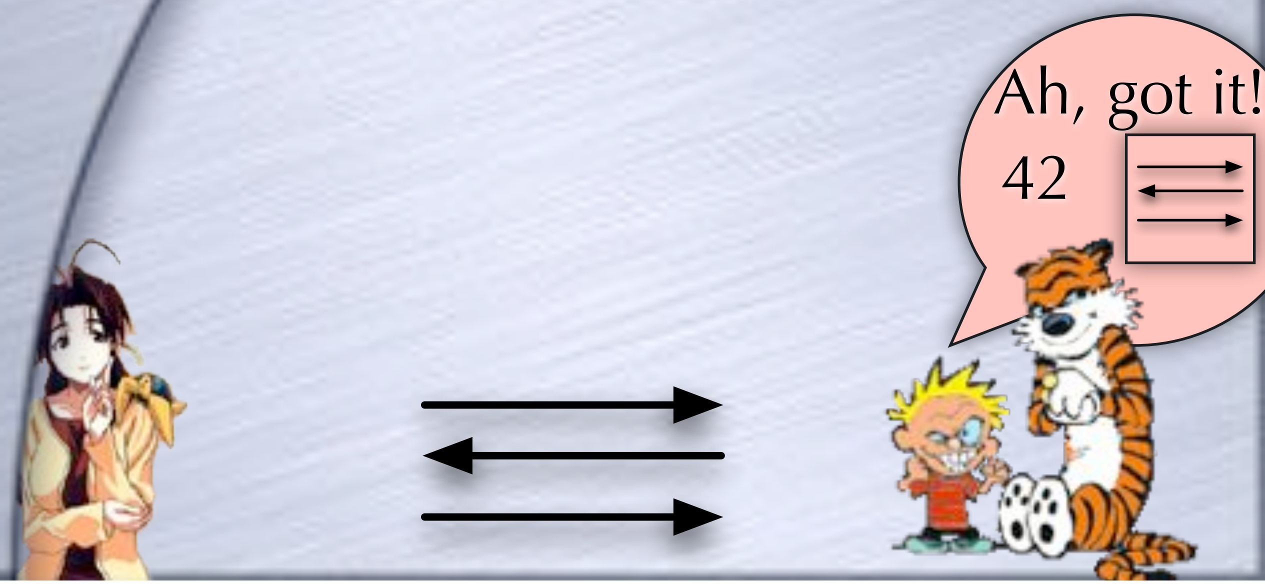

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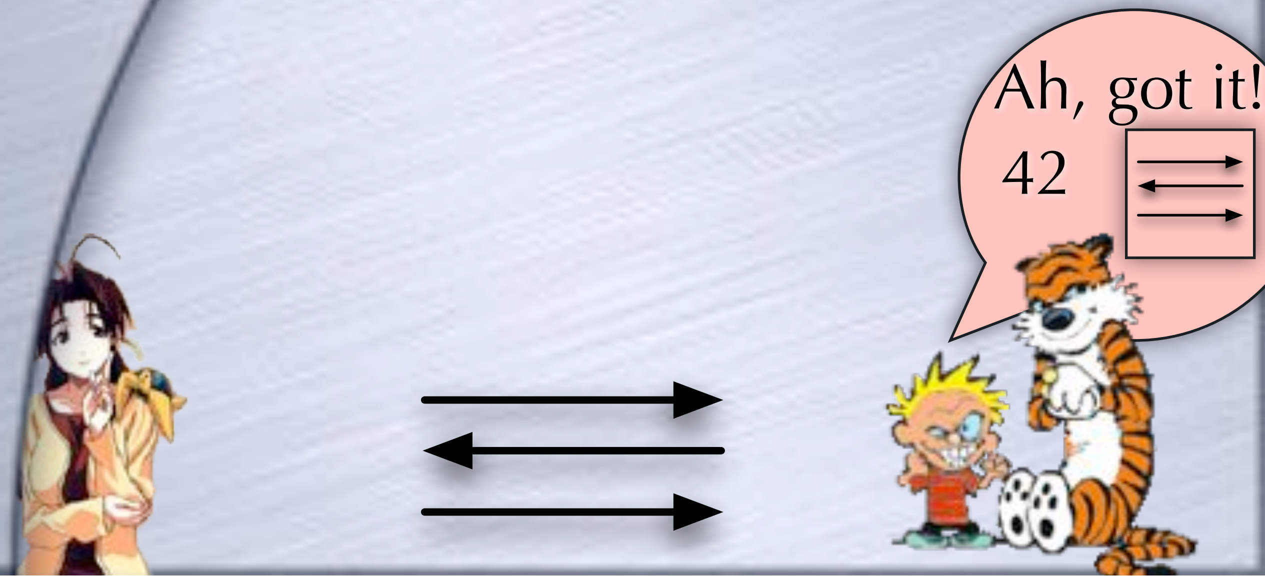

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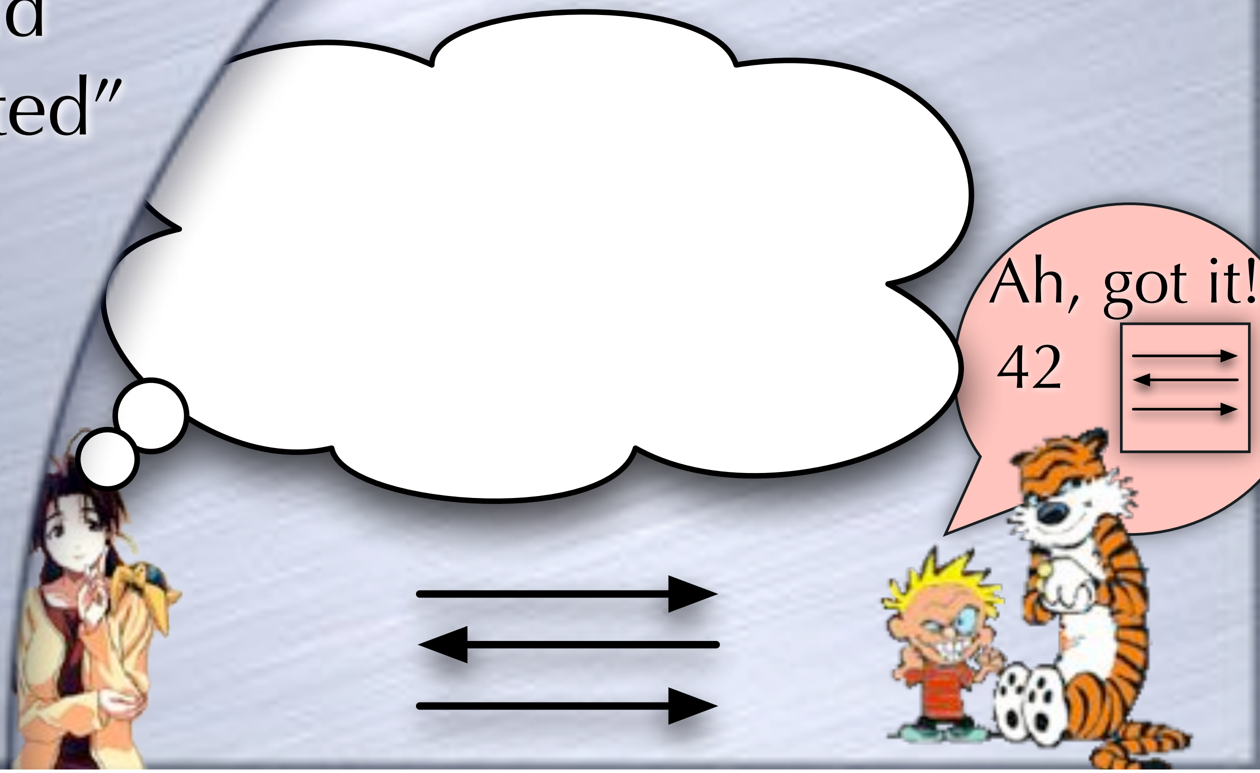

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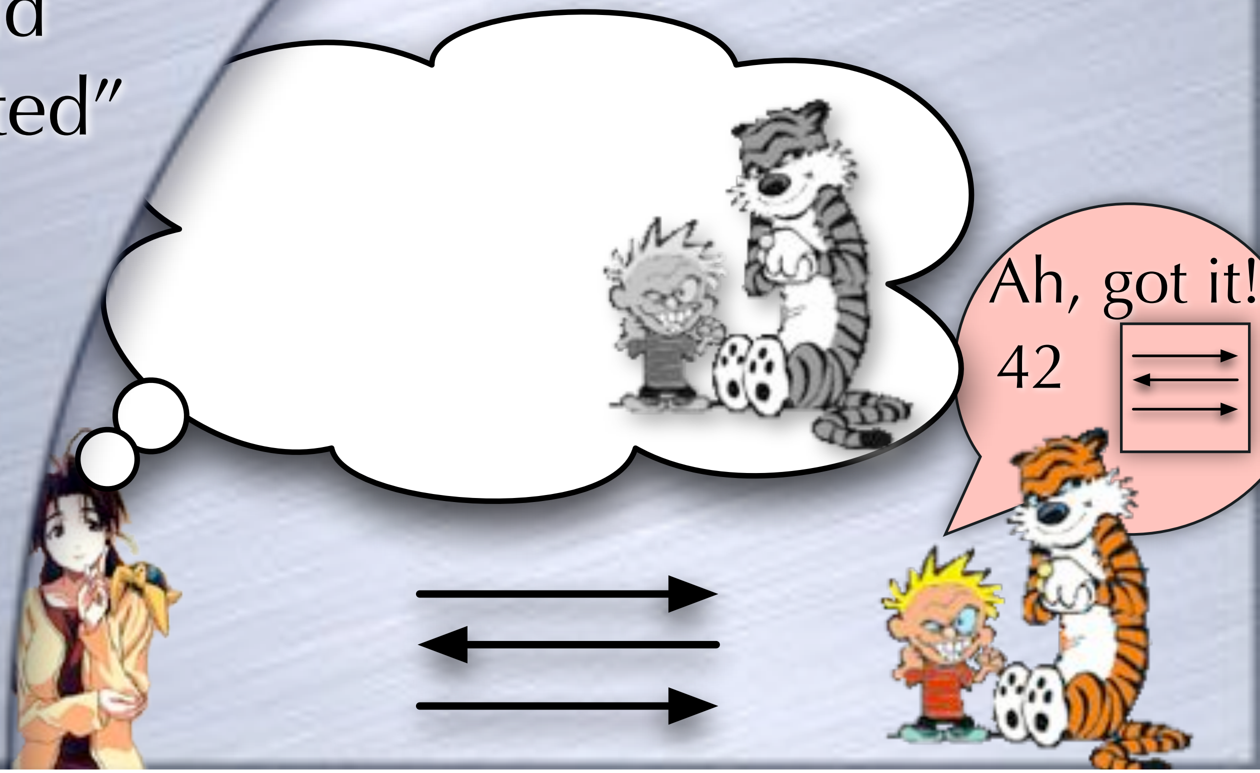

Zero-Knowledge Proofs

- Interactive Proof
  - Complete and Sound
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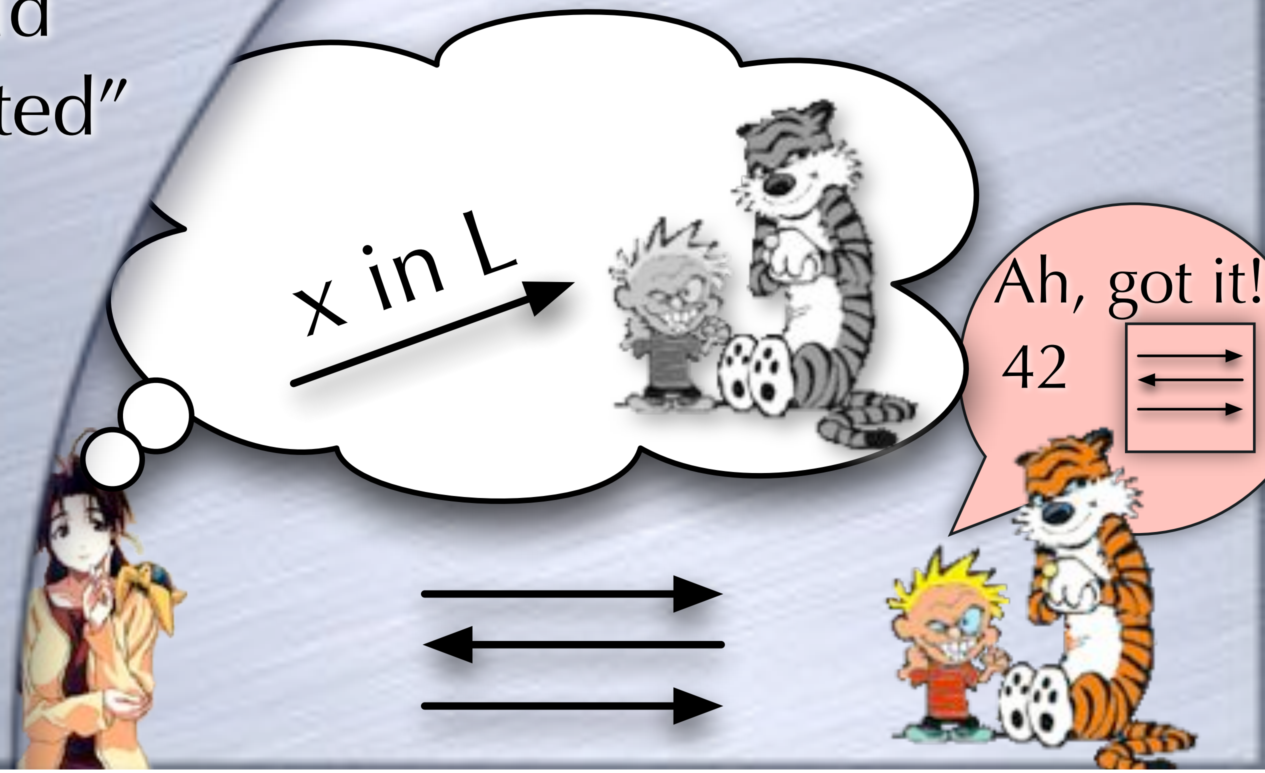

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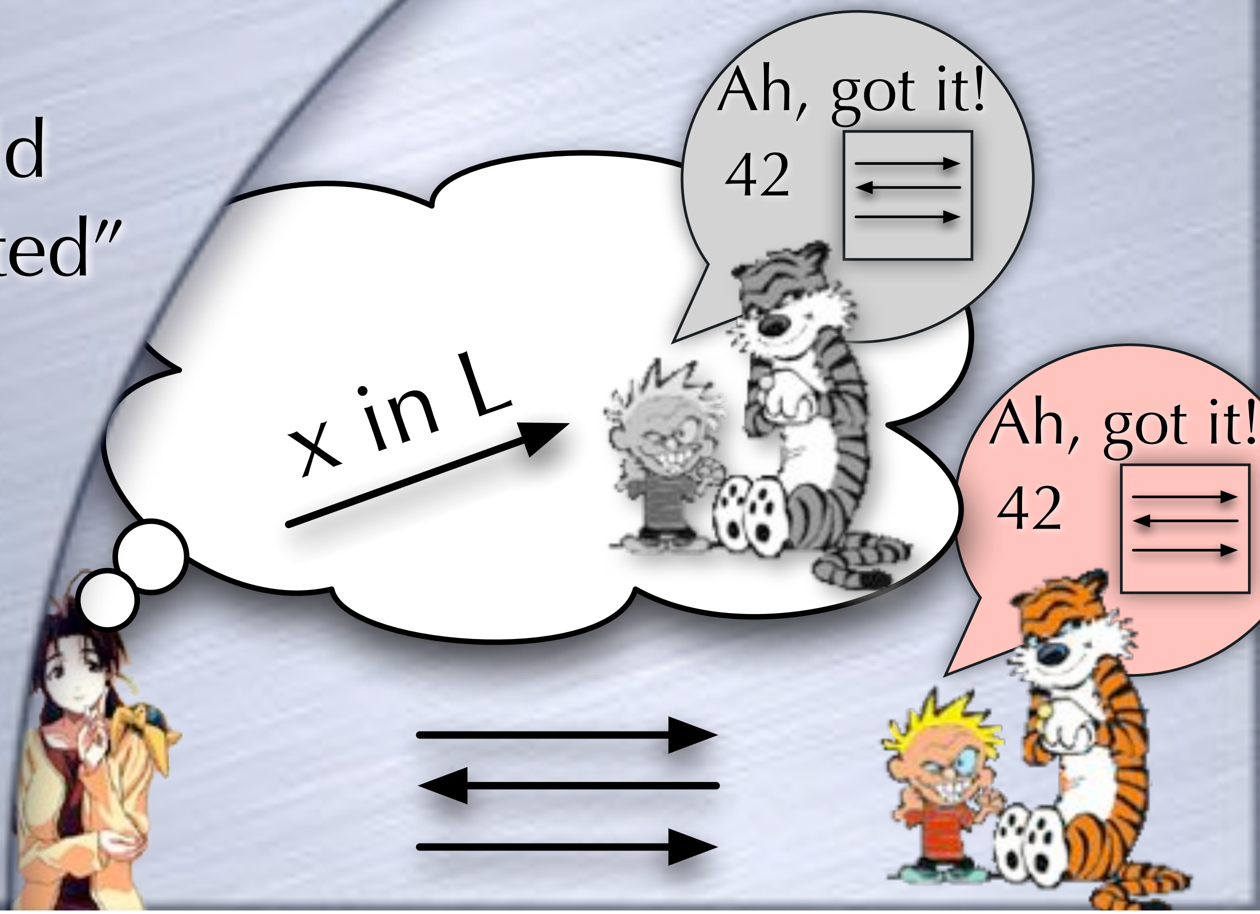

Zero-Knowledge Proofs

- Interactive Proof
  - Complete and Sound
- ZK Property:
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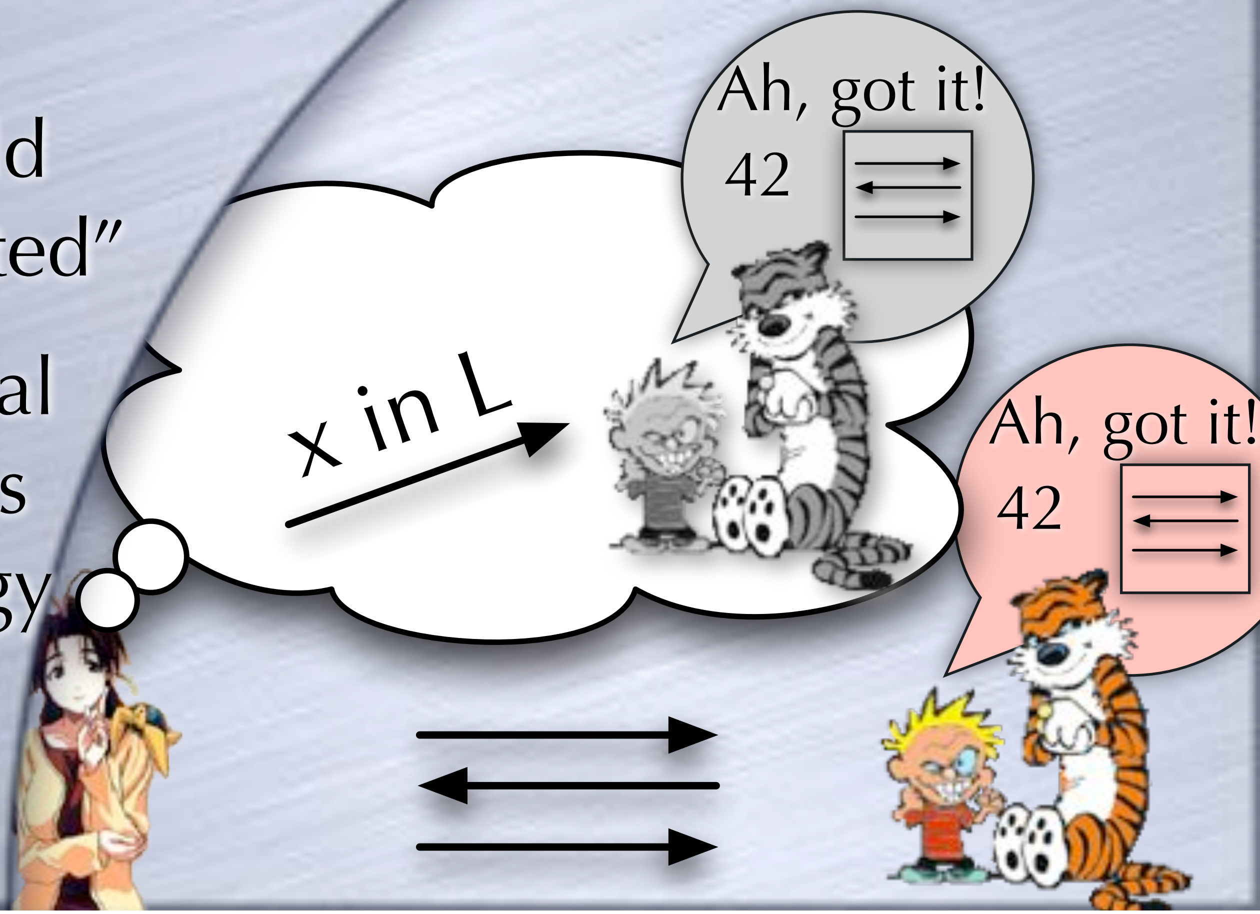
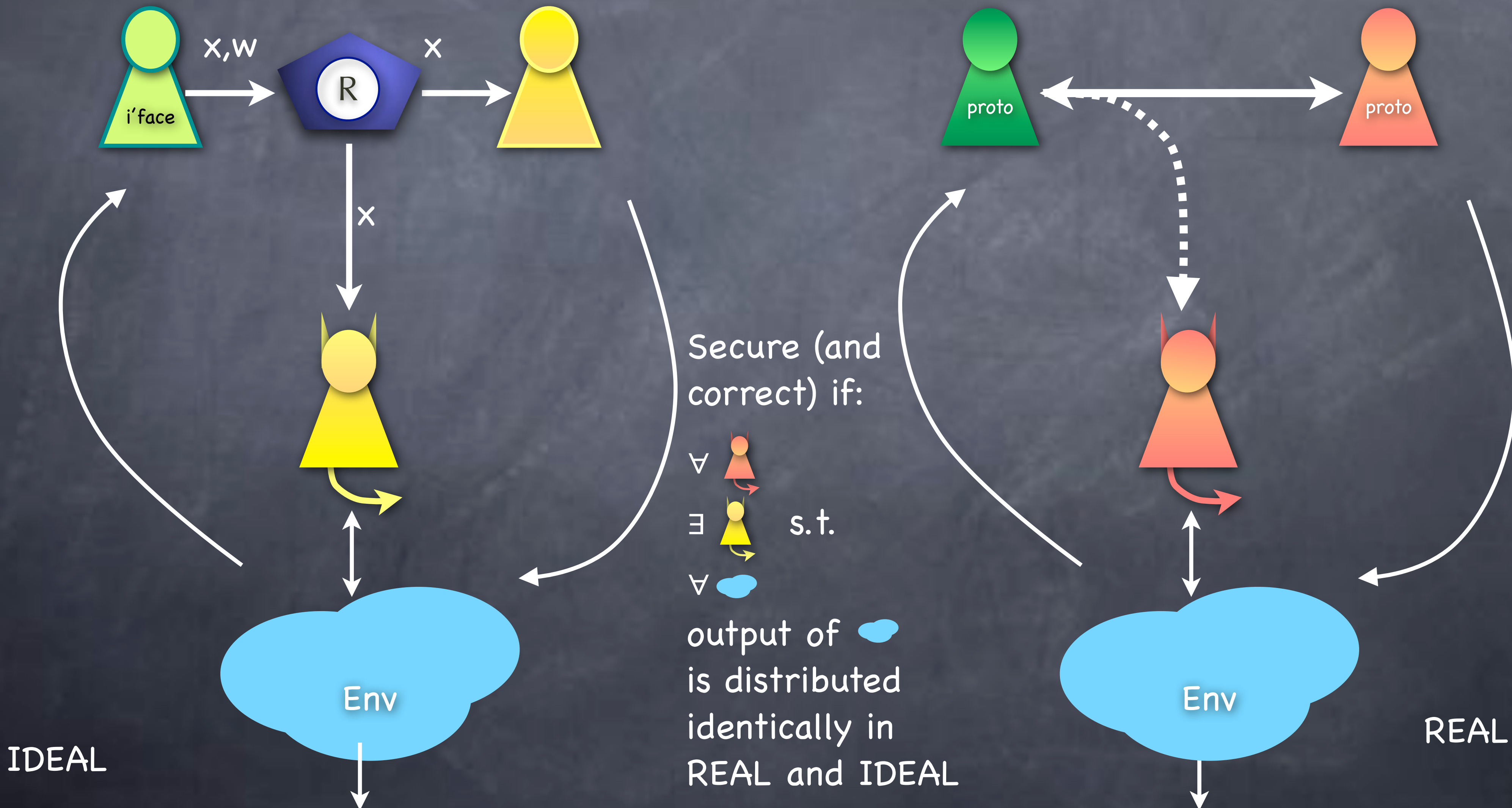
  - For every adversarial strategy, there exists a simulation strategy



ZK Property (in other pict's)



Secure (and correct) if:

∀ [adversary in REAL]

∃ [adversary in IDEAL] s.t.

∀ [environment]

output of [environment] is distributed identically in REAL and IDEAL

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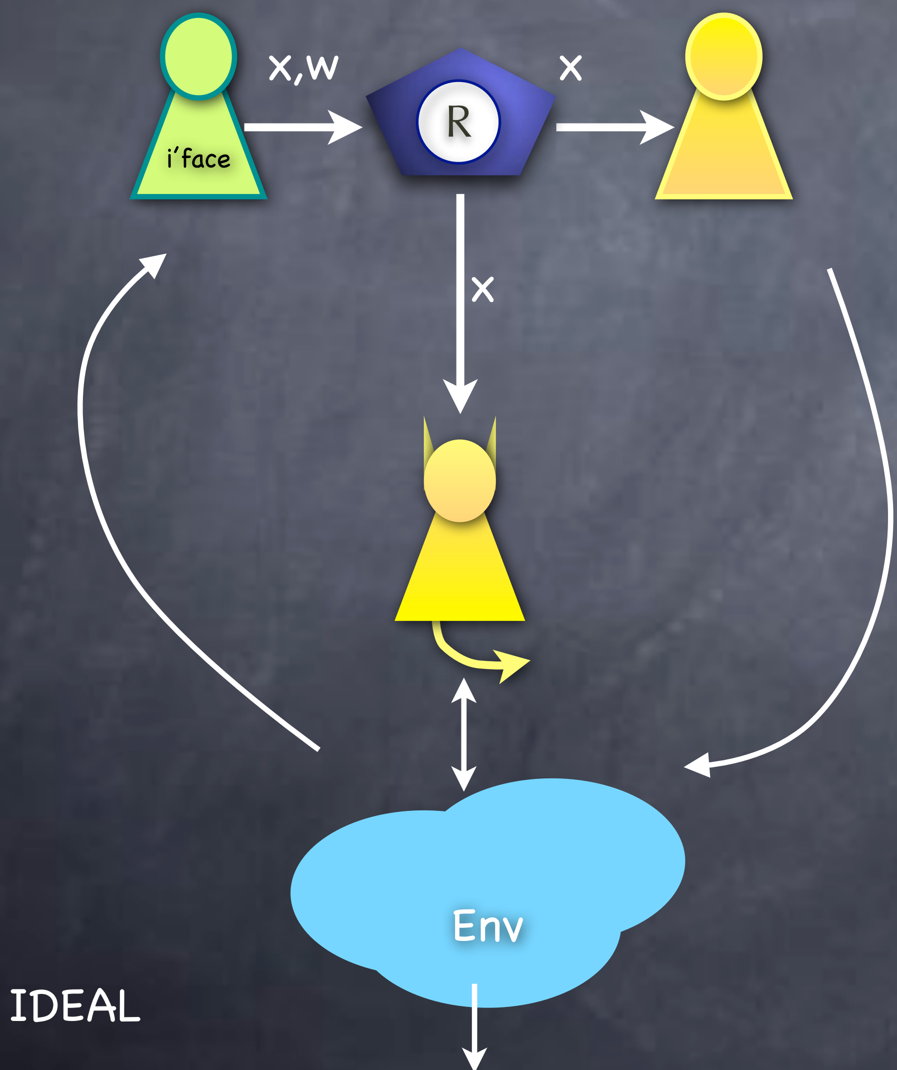

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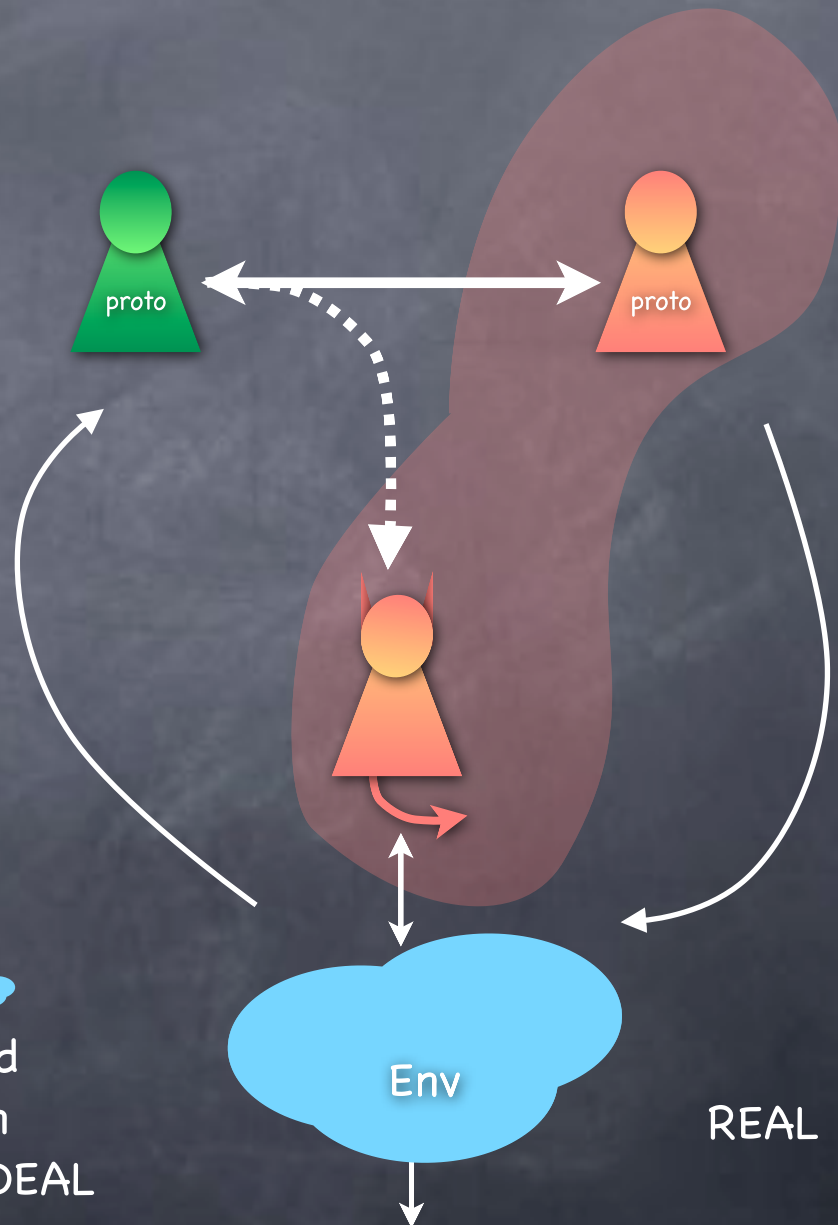

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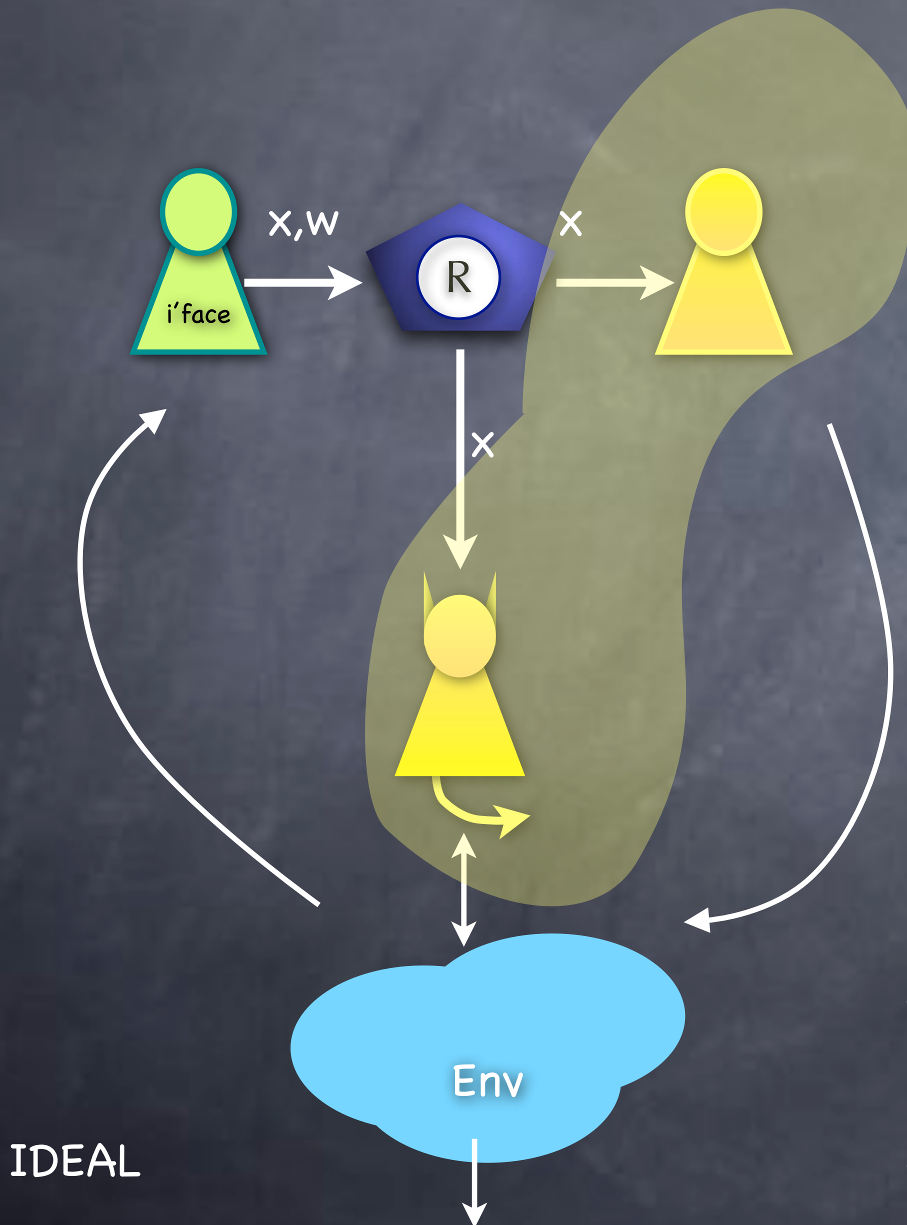

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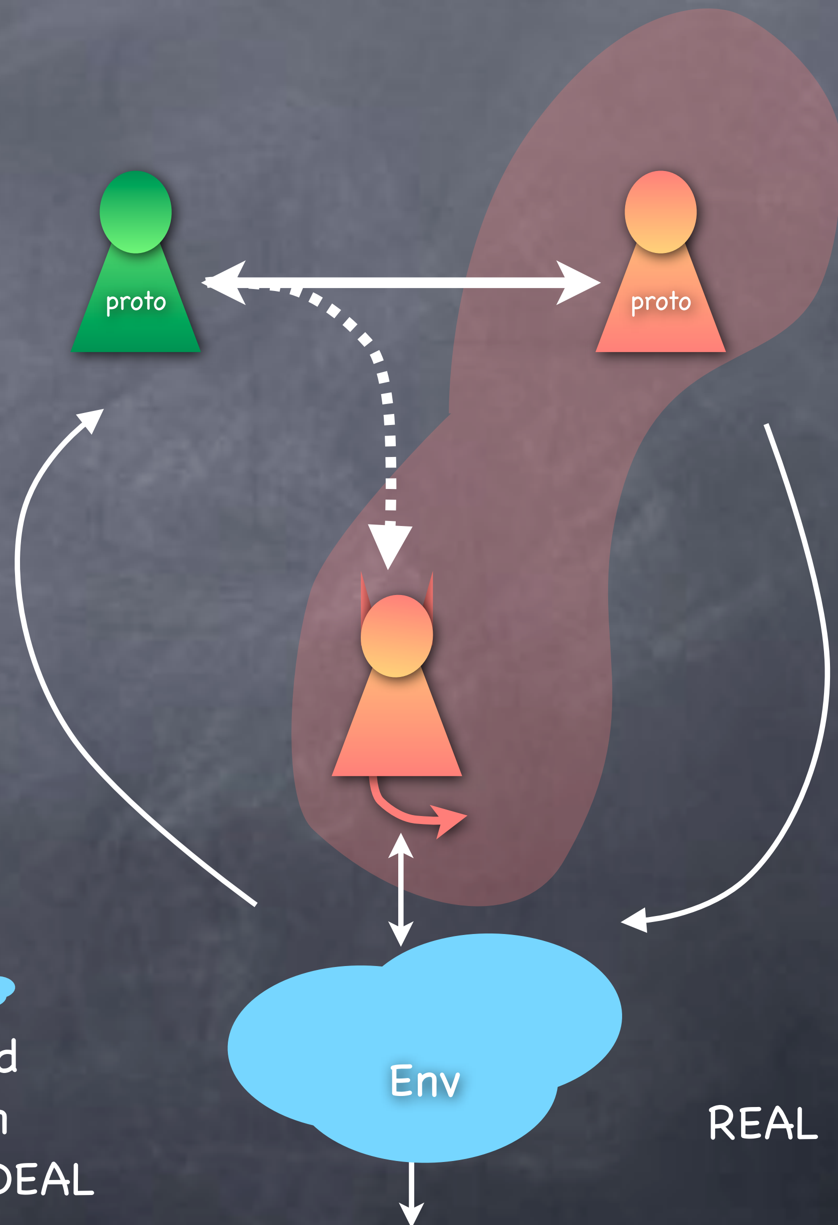
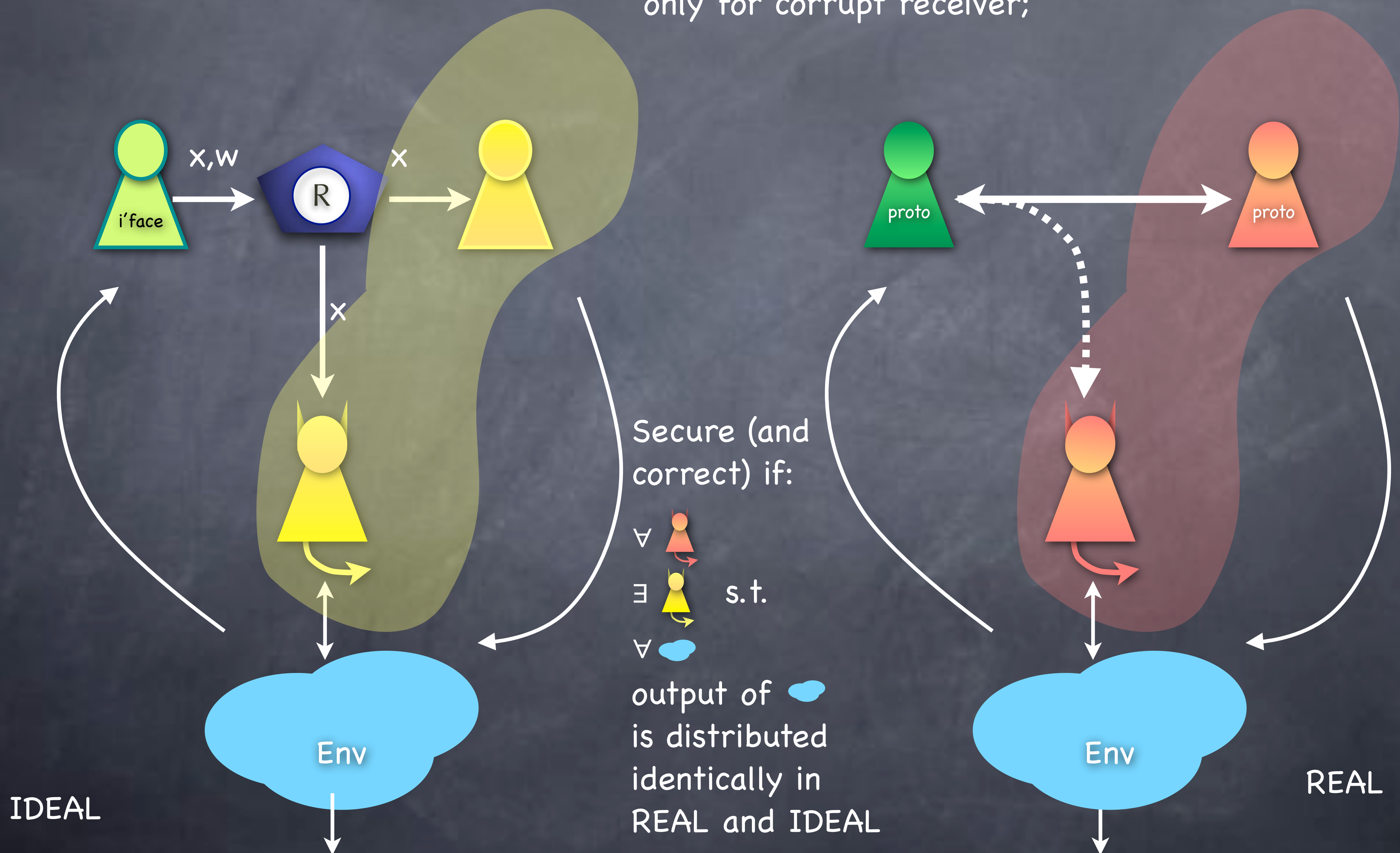


ZK Property (in other pict's)

Classical definition uses simulation only for corrupt receiver;



Secure (and correct) if:

∀ [corrupt party]

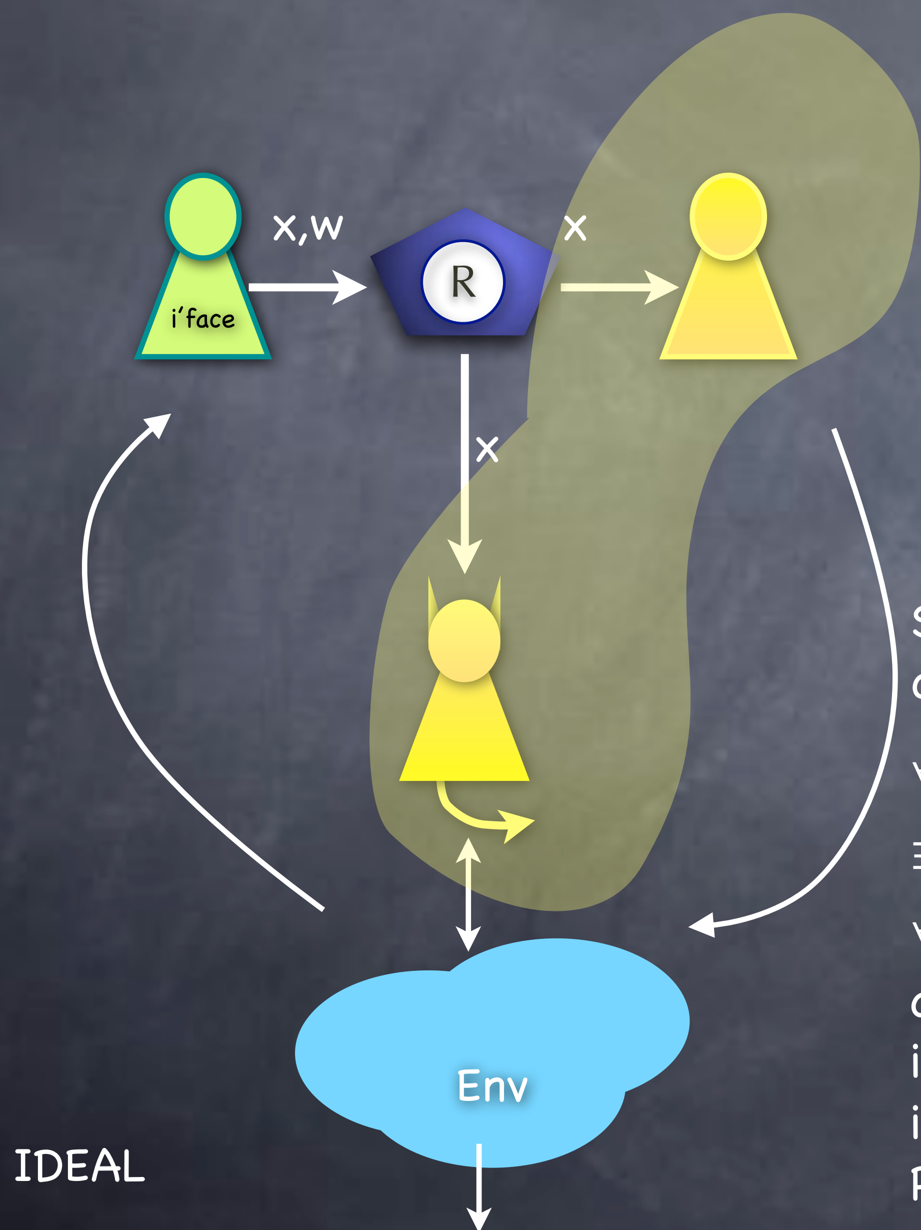
∃ [simulator] s.t.

∀ [environment]

output of [environment] is distributed identically in REAL and IDEAL

ZK Property (in other pict's)

Classical definition uses simulation only for corrupt receiver; and uses only standalone security: Environment gets only a transcript at the end



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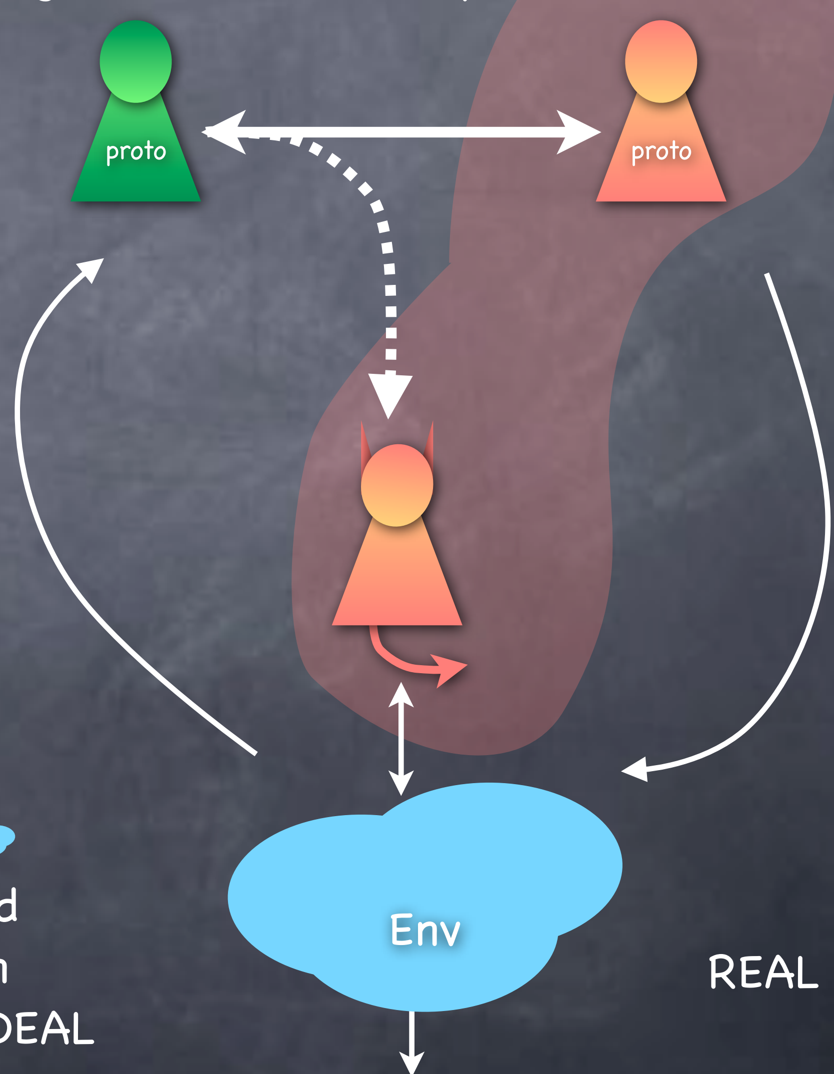
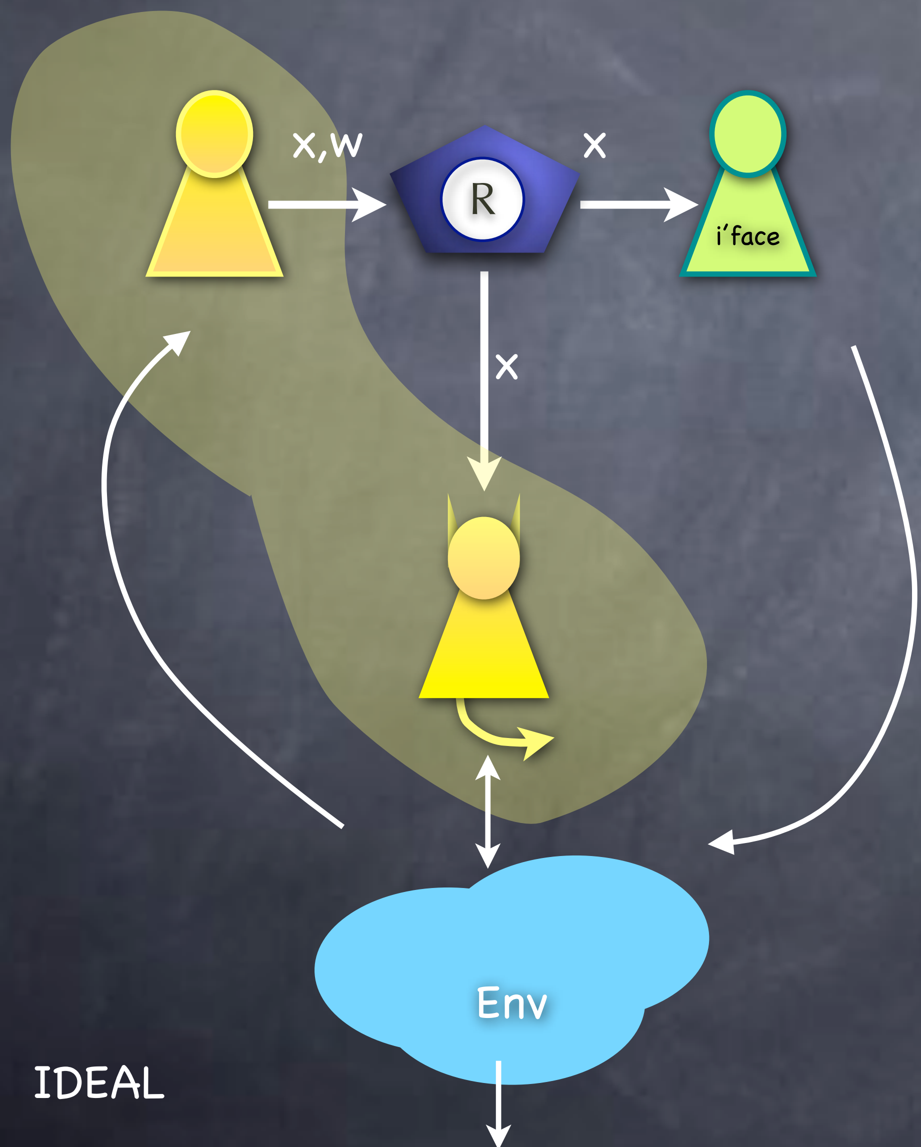


SIM ZK



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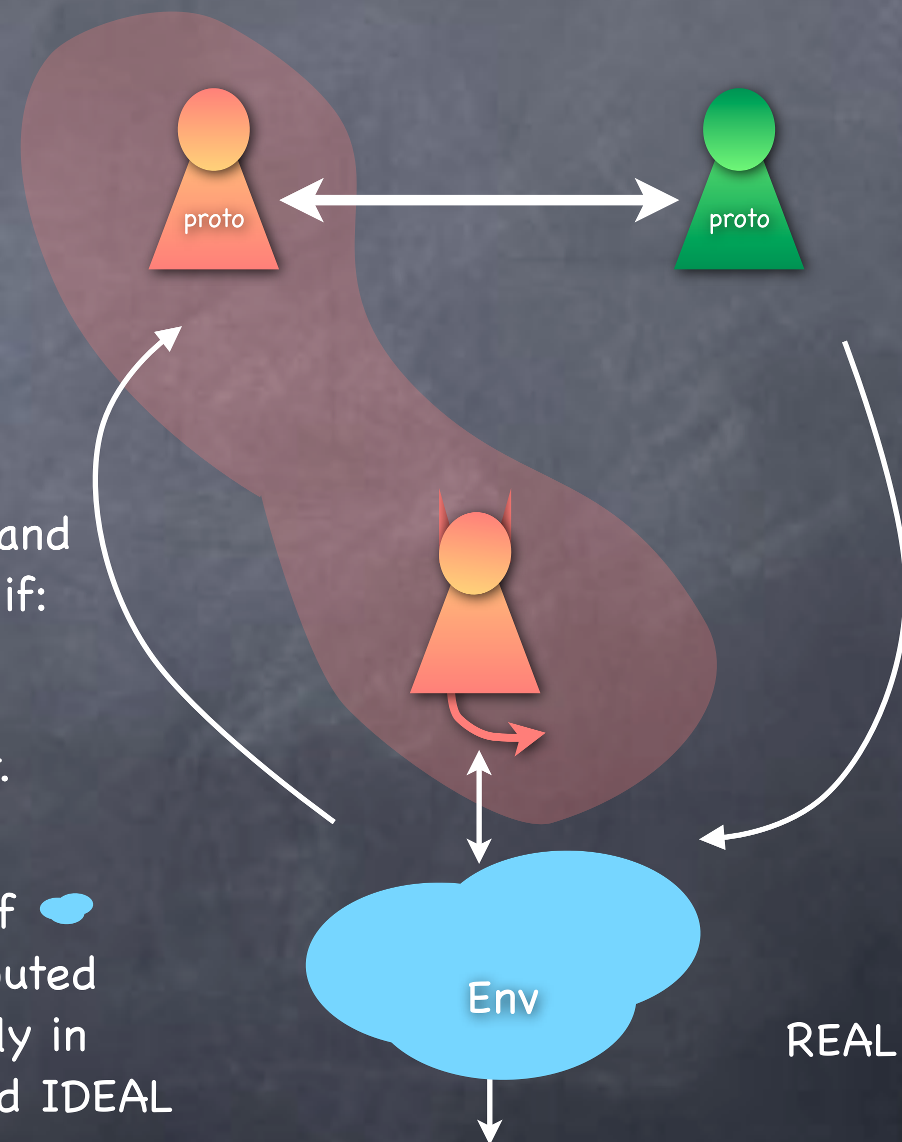
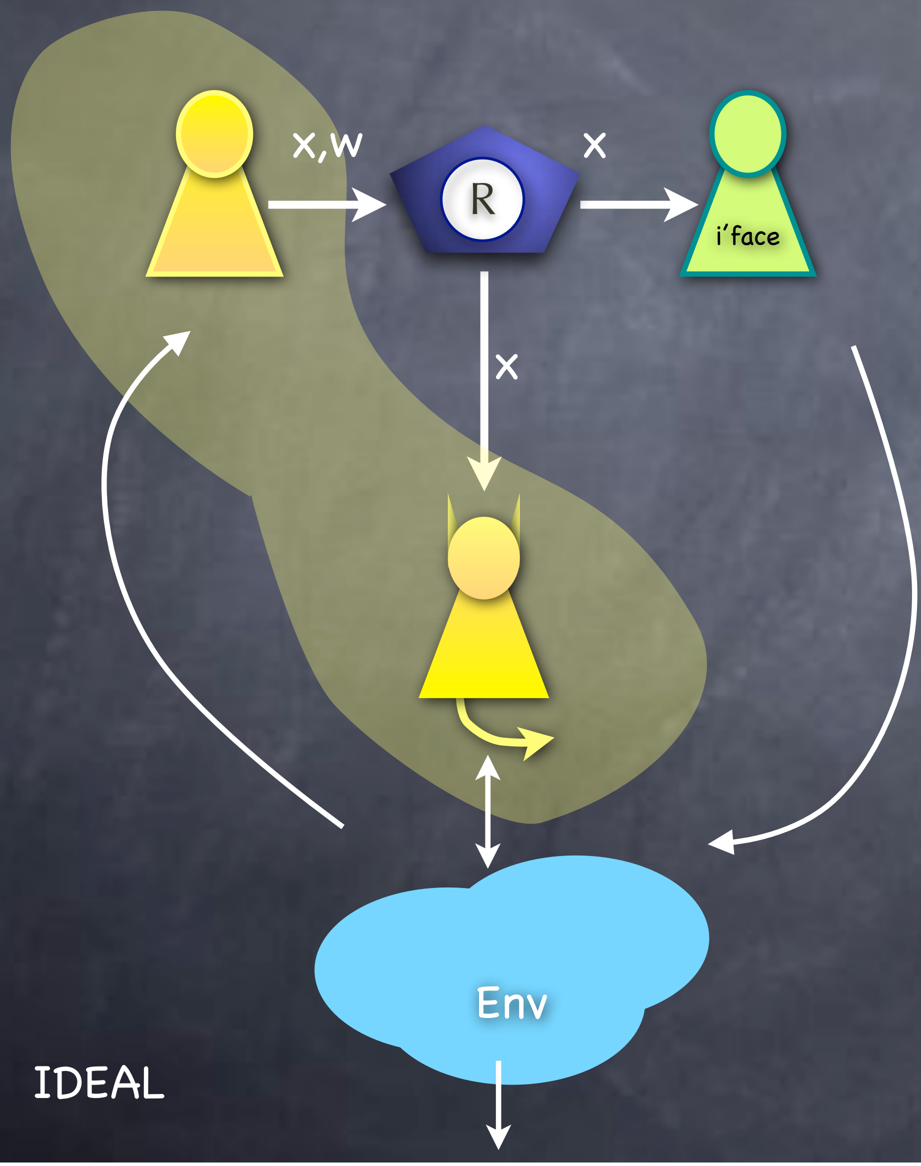


SIM ZK

- SIM-ZK would require simulation also when prover is corrupt



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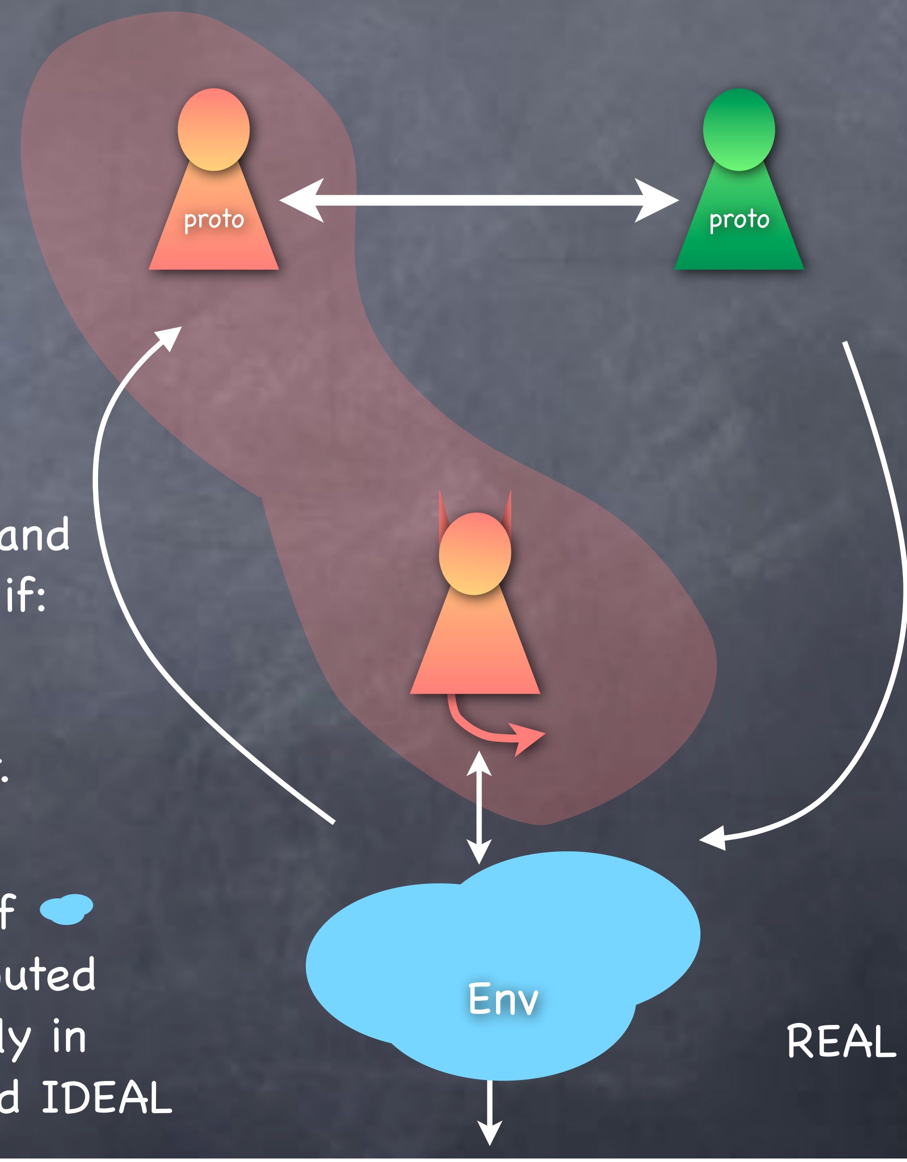

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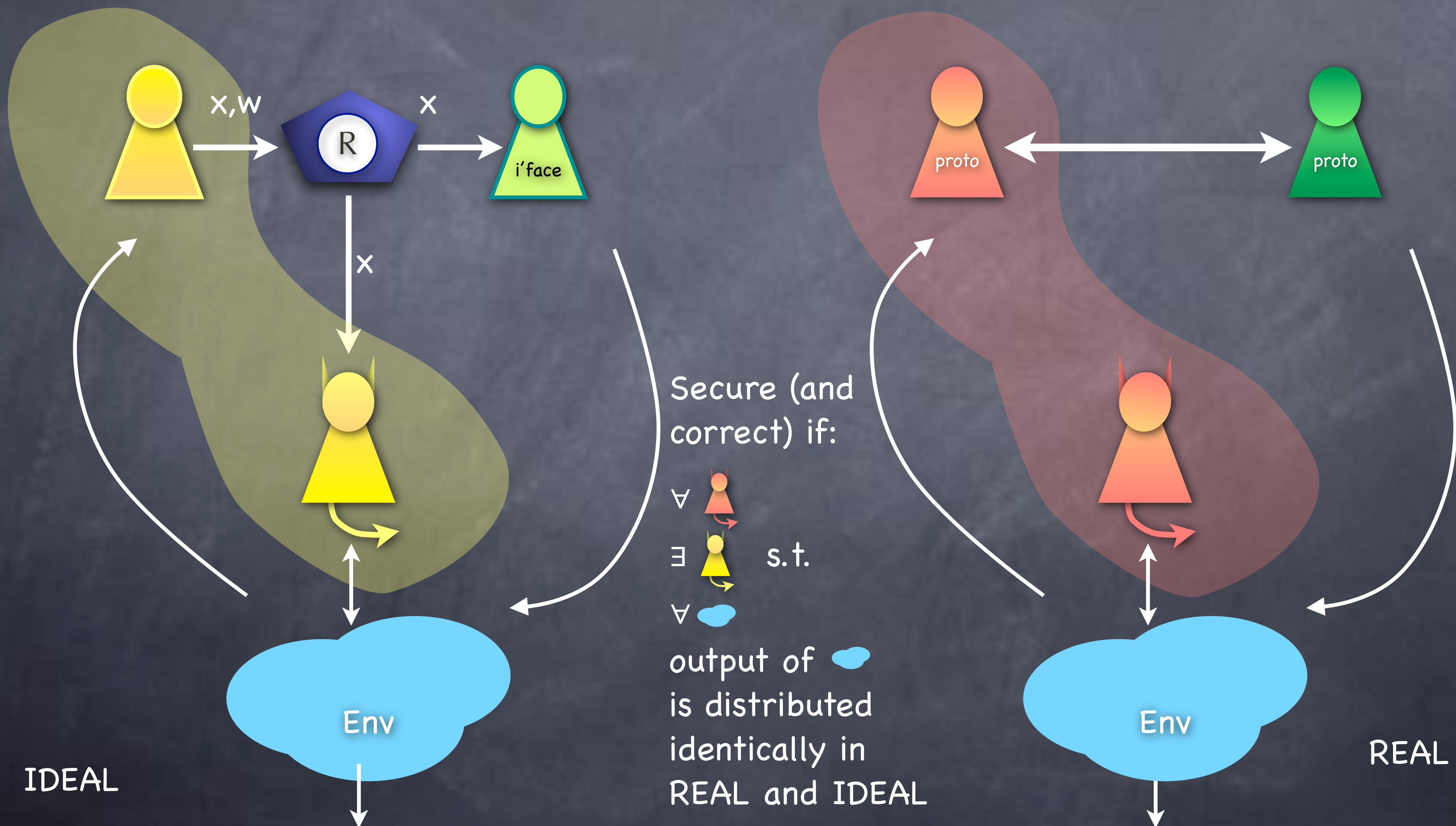
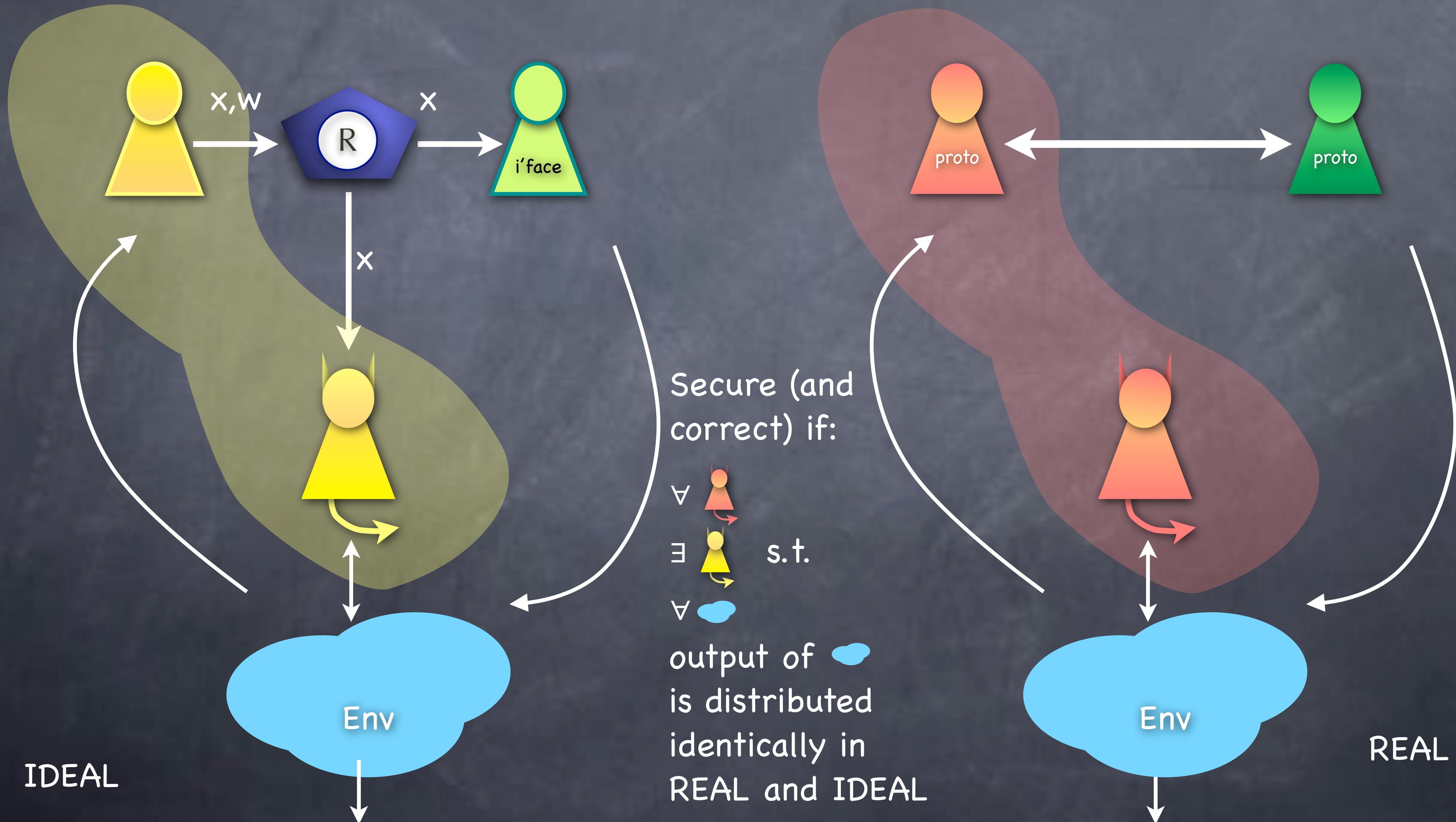


SIM ZK

- SIM-ZK would require simulation also when prover is corrupt
  - Then simulator is a witness extractor
- Adding this (in standalone) makes it a Proof of Knowledge



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  - ZKPoK, Statistical ZK Arguments, O(1)-round ZK, ...

A ZK Proof for Graph Colorability

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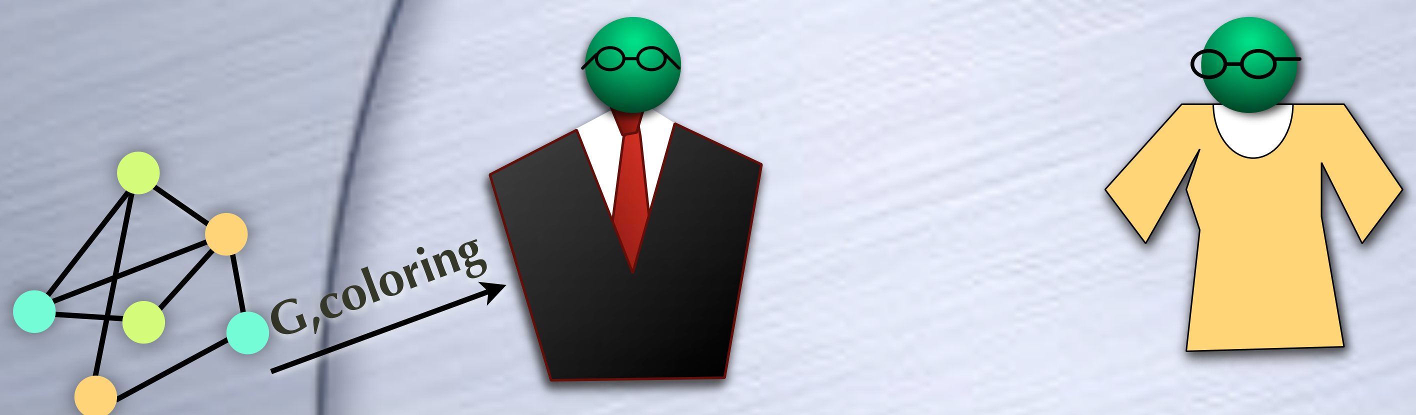
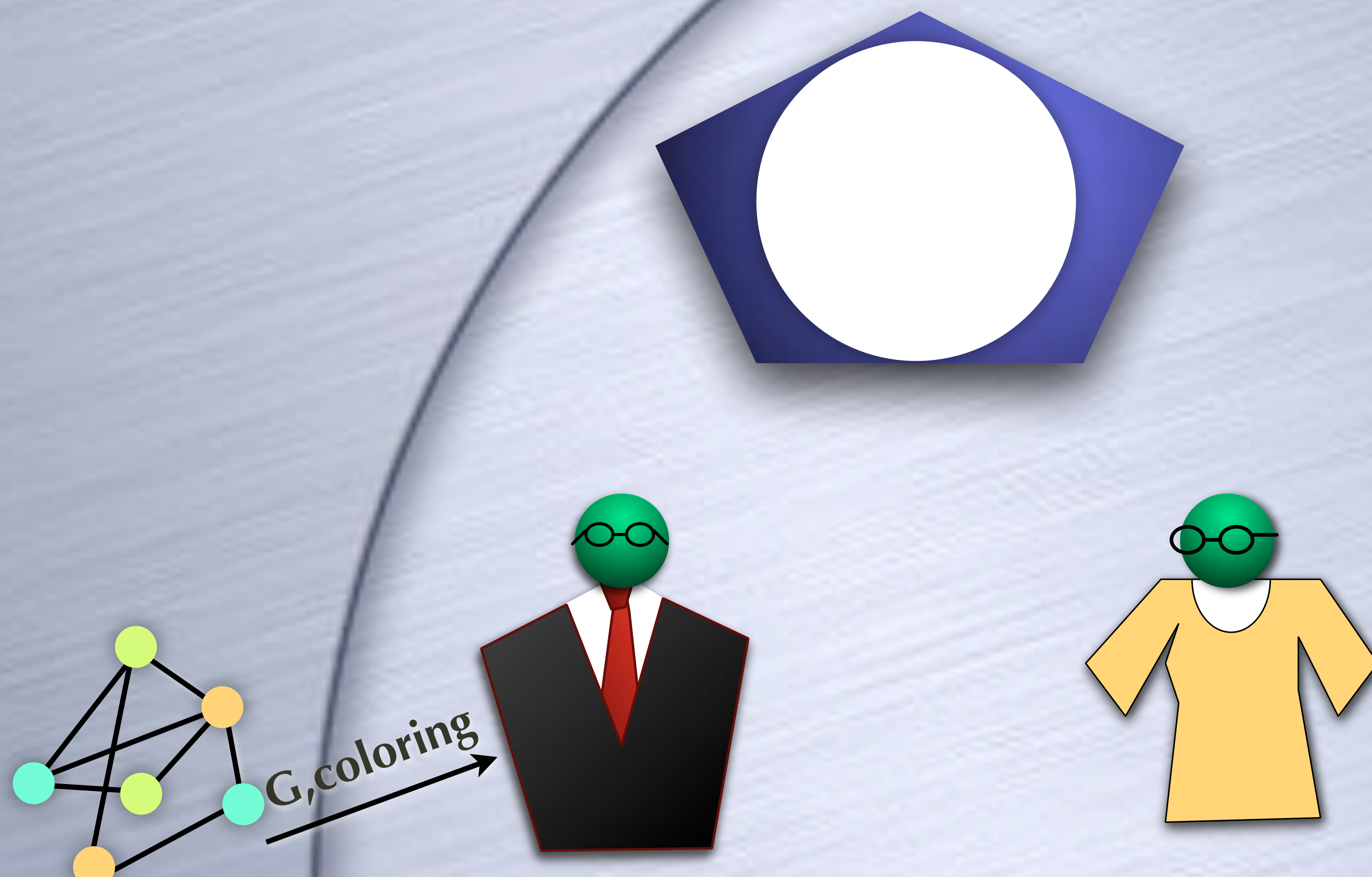


A ZK Proof for Graph Colorability

- Uses a commitment protocol as a subroutine



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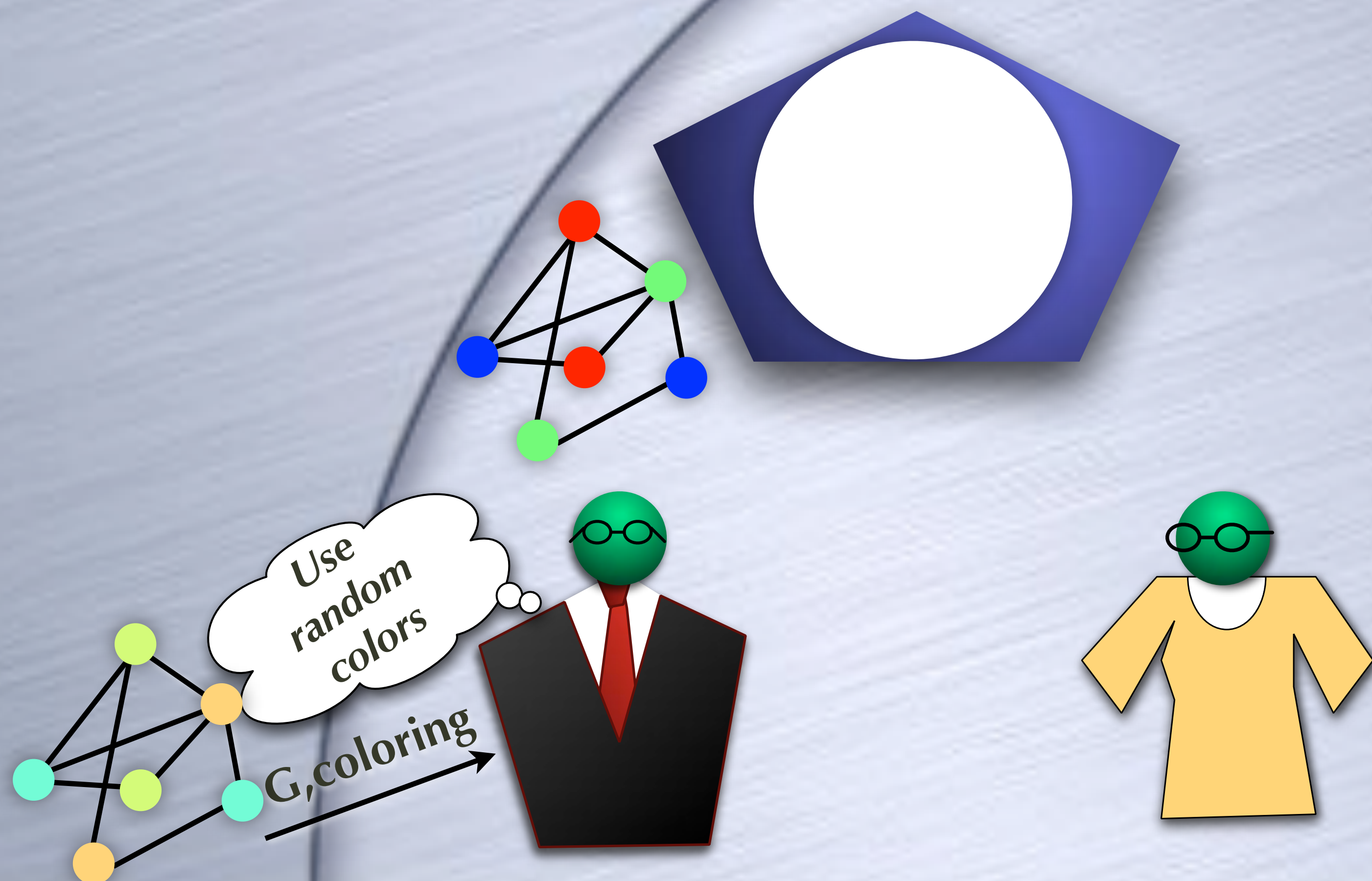

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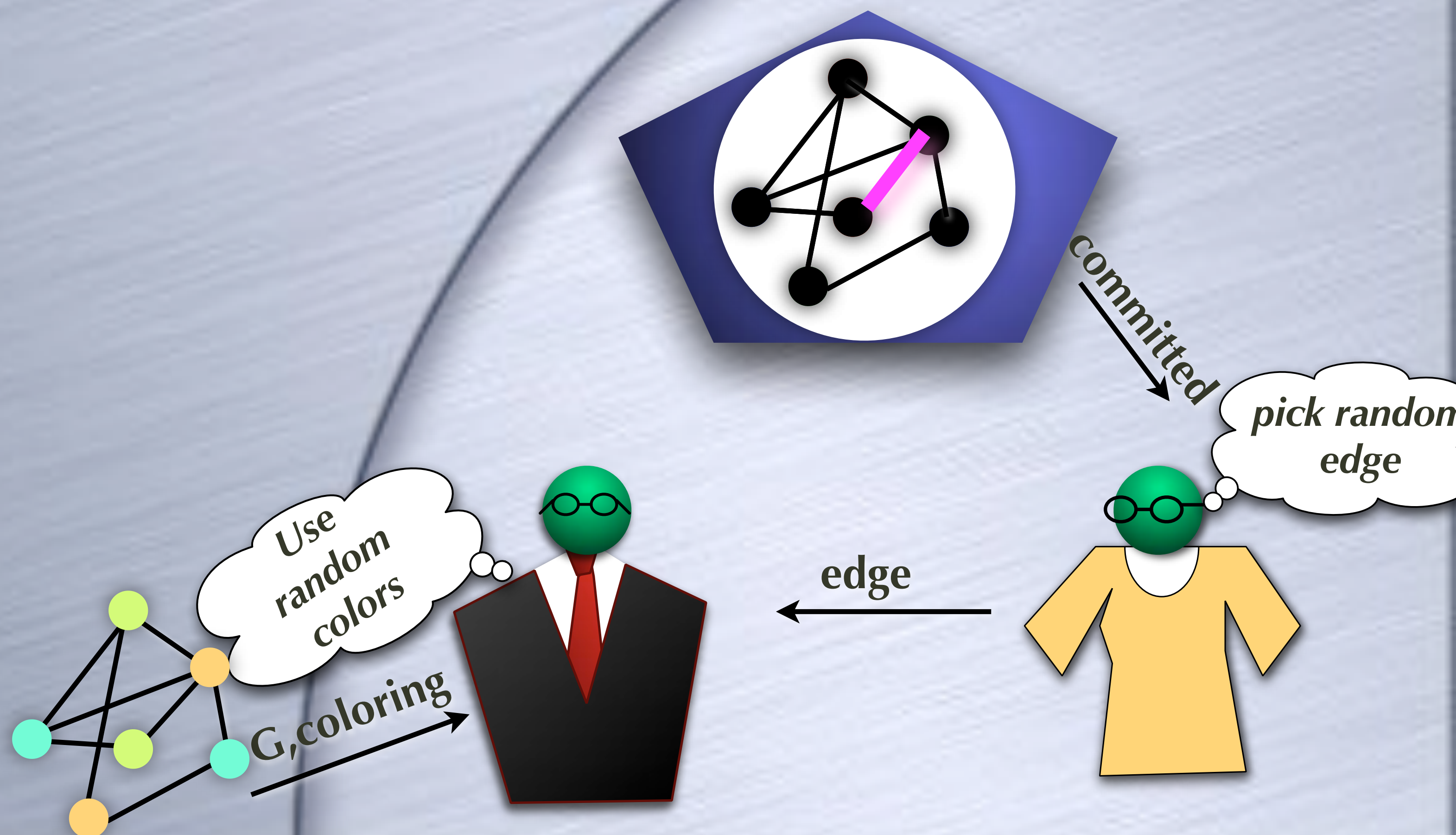

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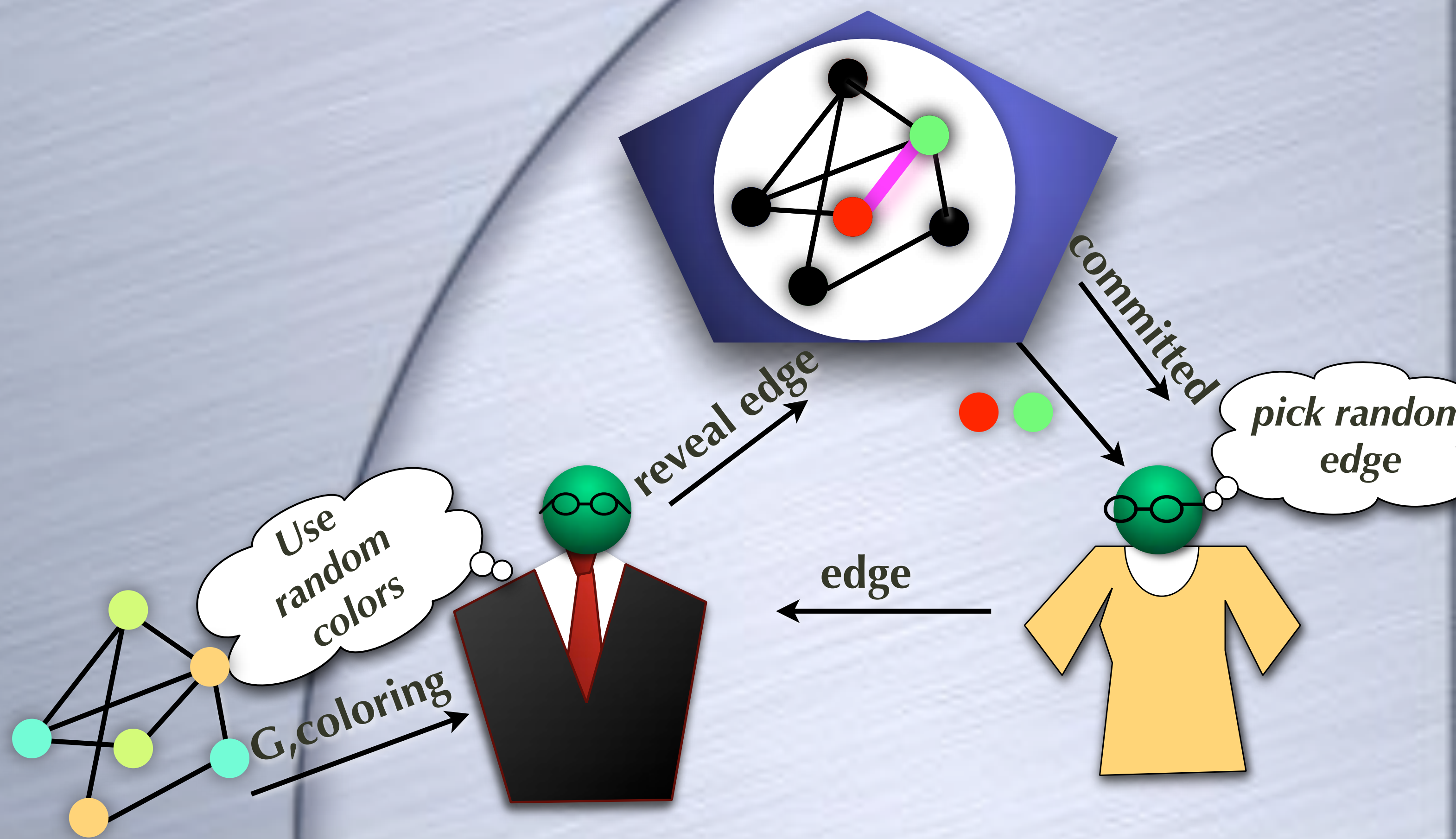

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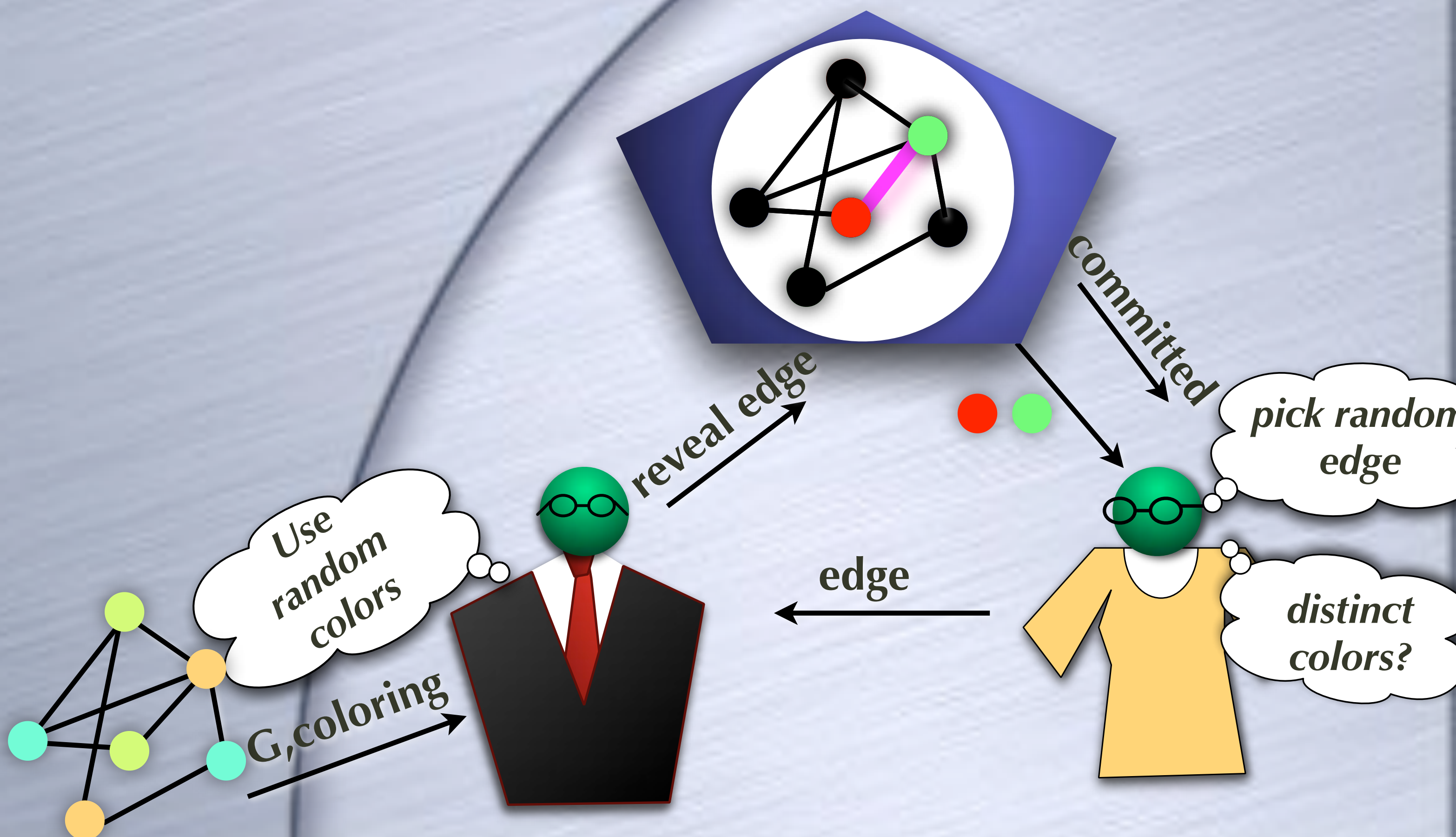

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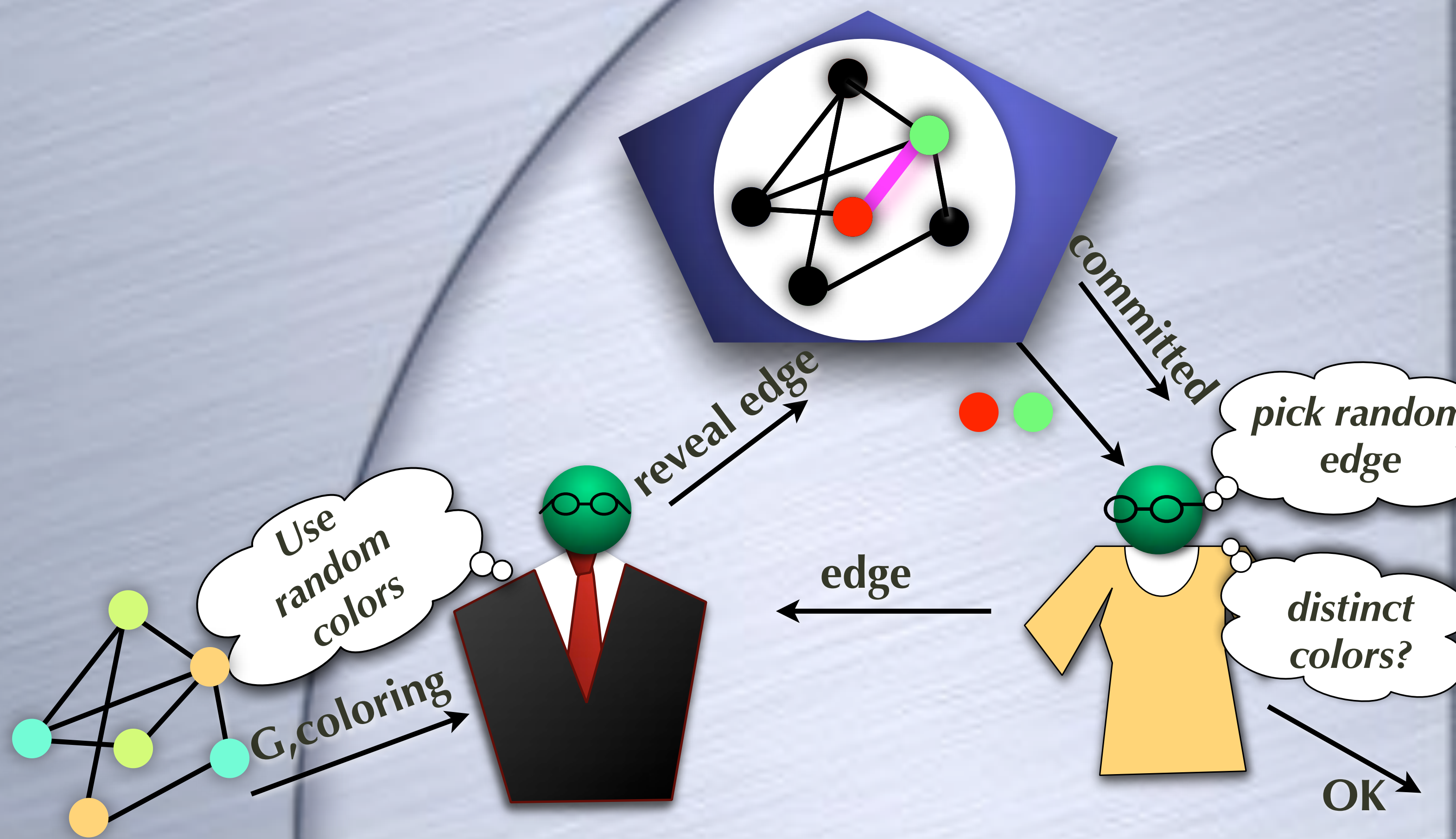

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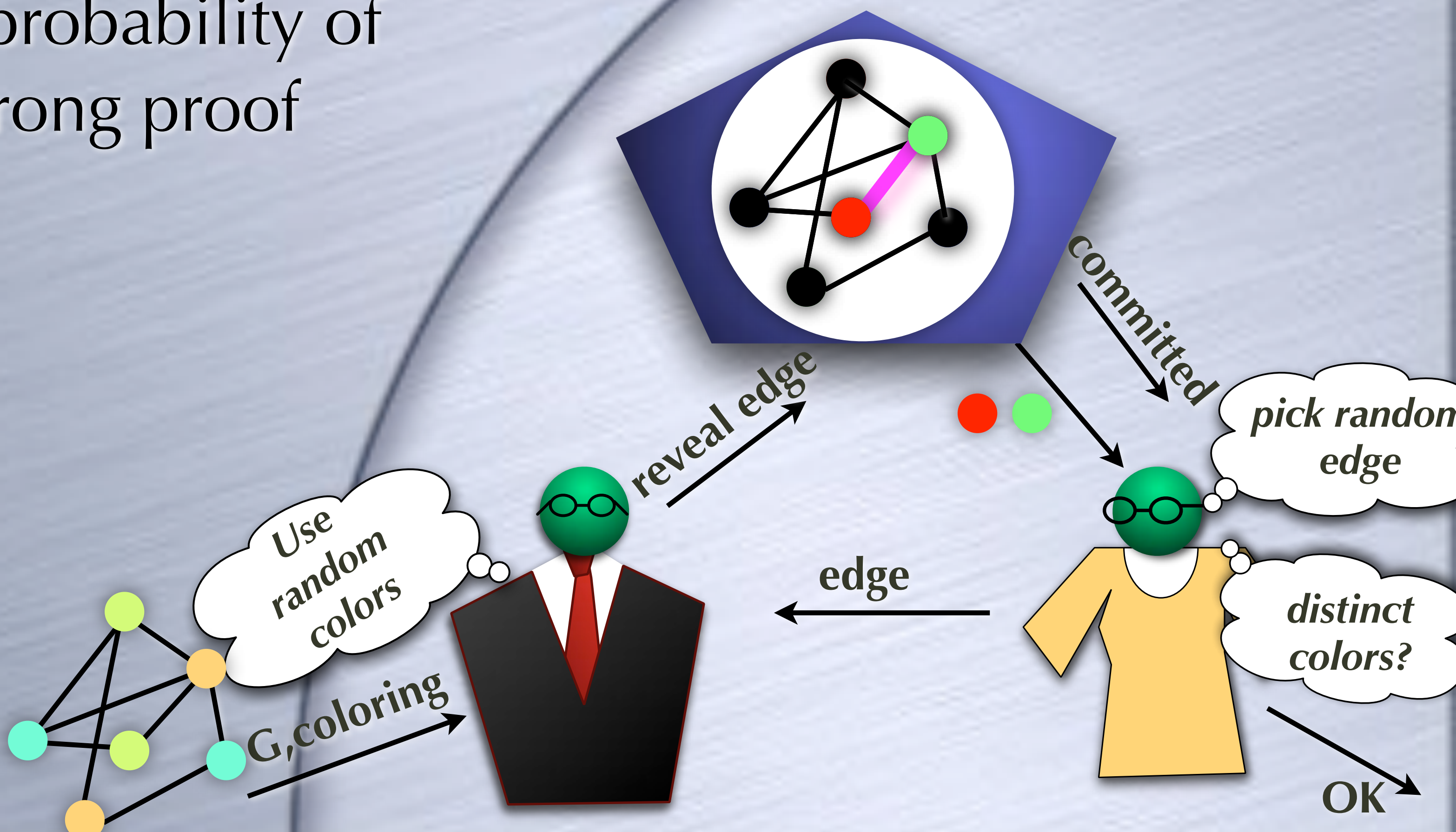
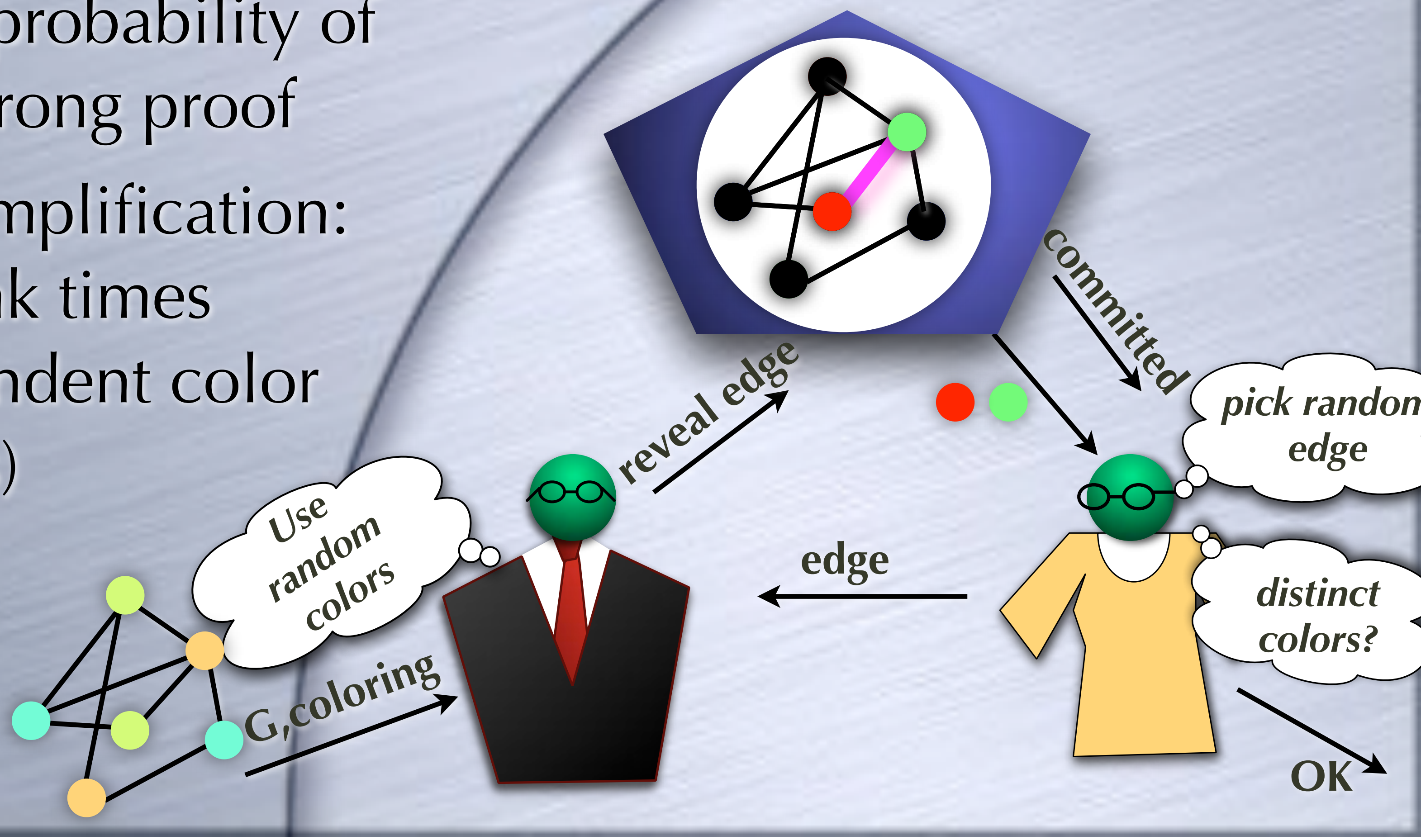


A ZK Proof for Graph Colorability

- Uses a commitment protocol as a subroutine
- At least 1/m probability of catching a wrong proof
- Soundness amplification: Repeat say mk times (with independent color permutations)



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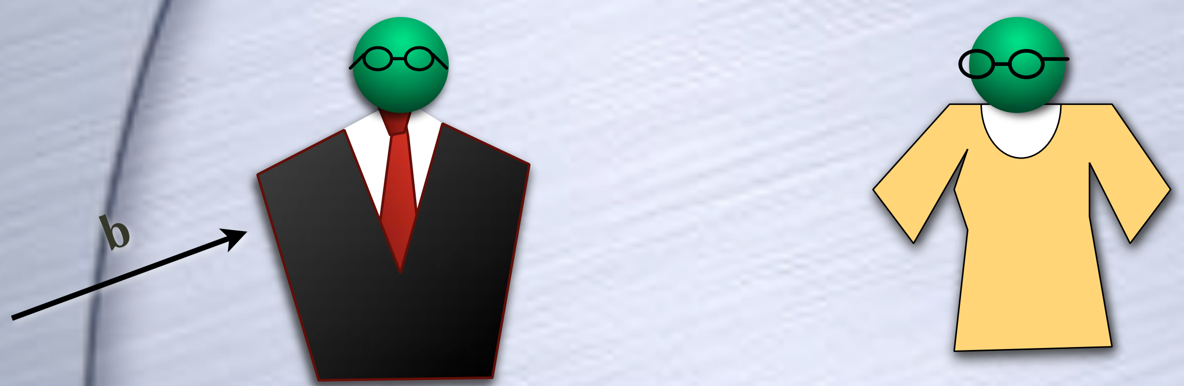

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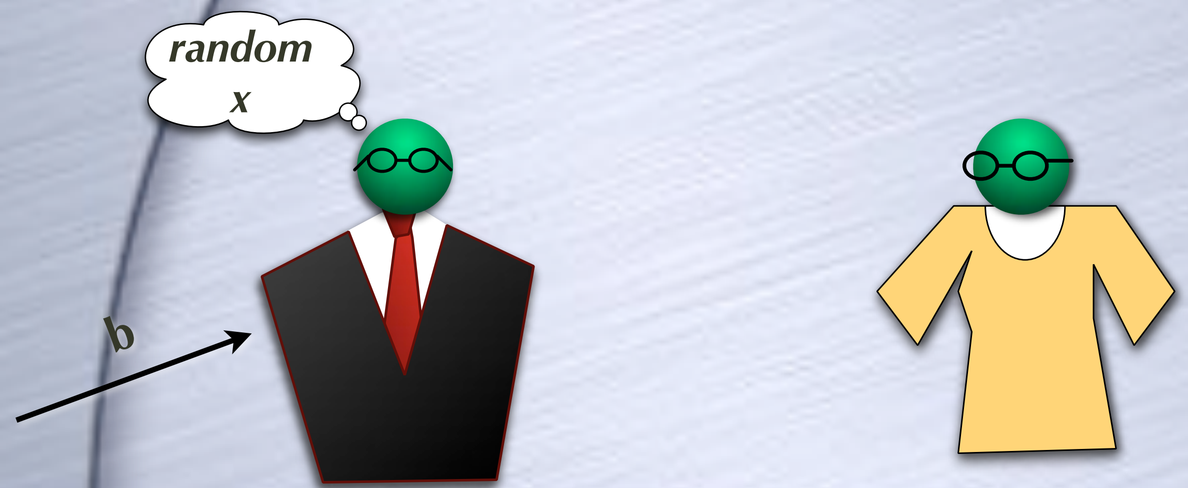

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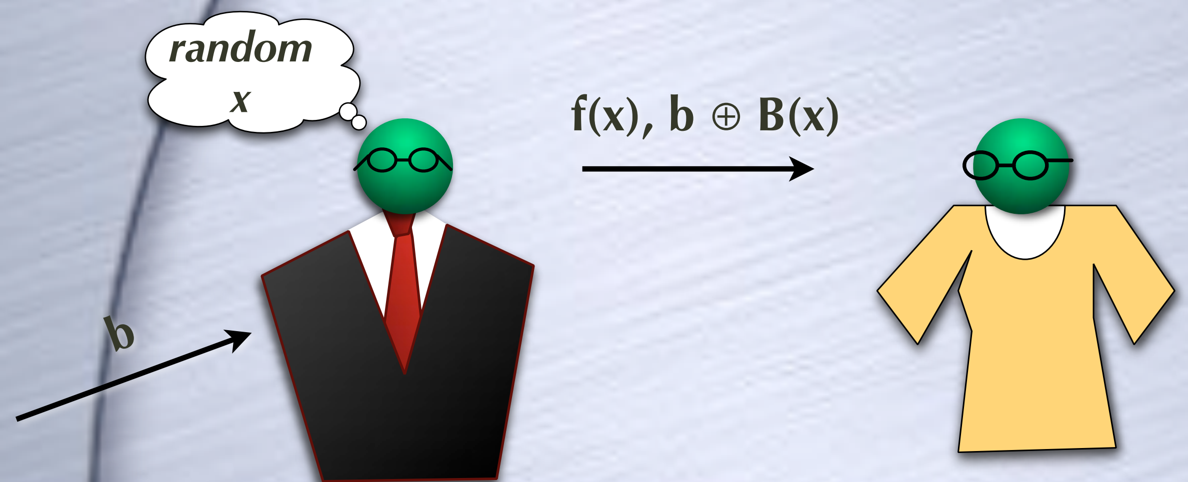

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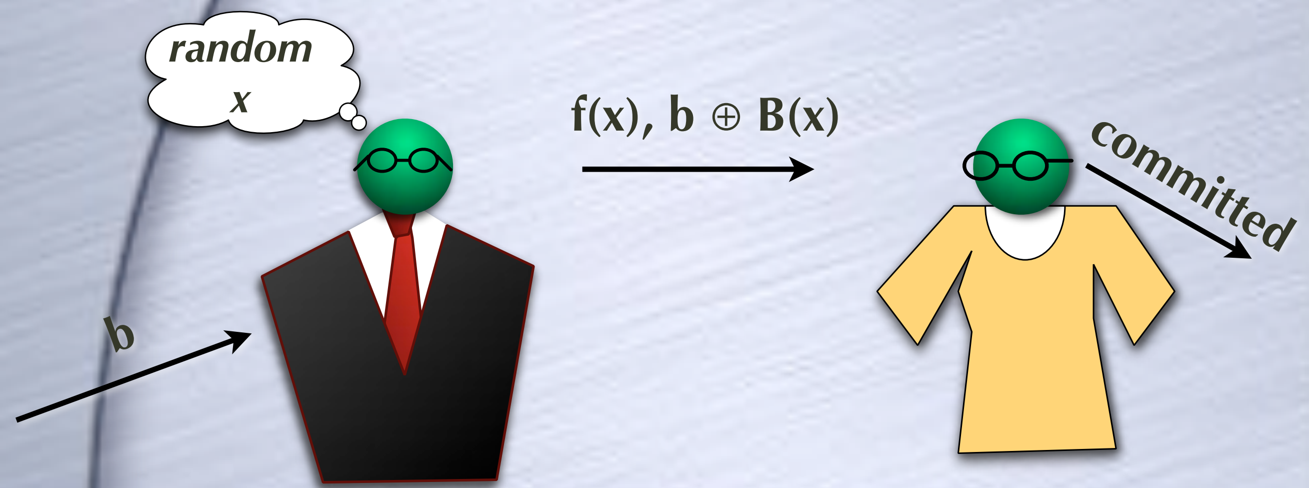

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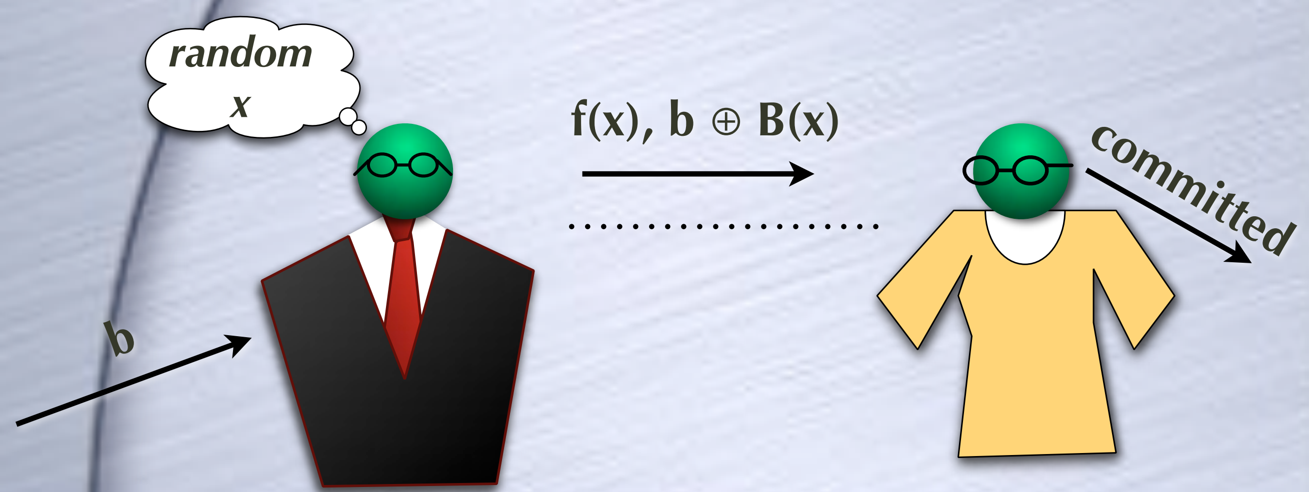

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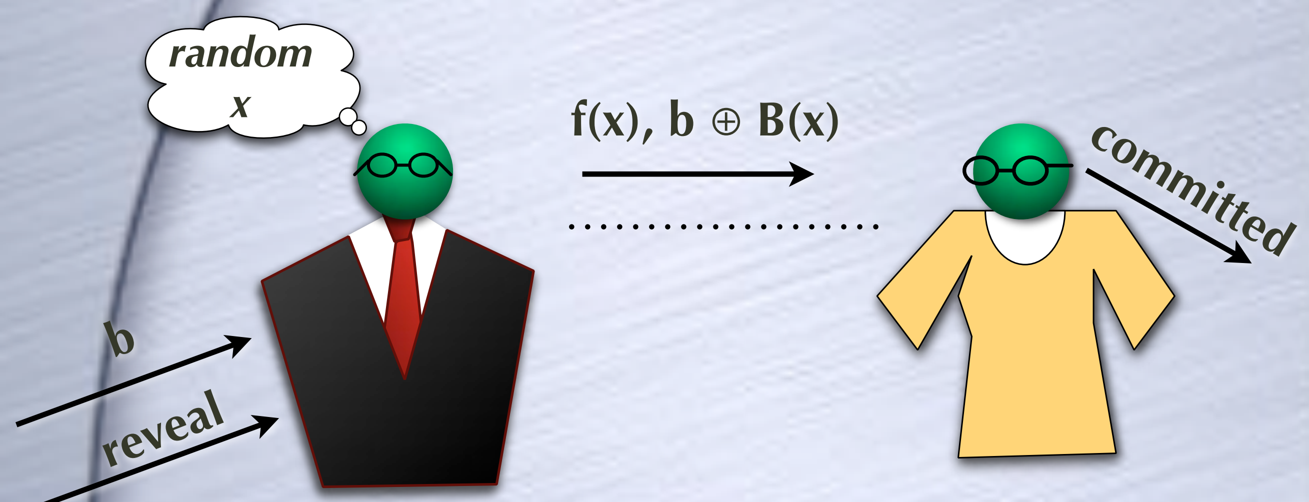

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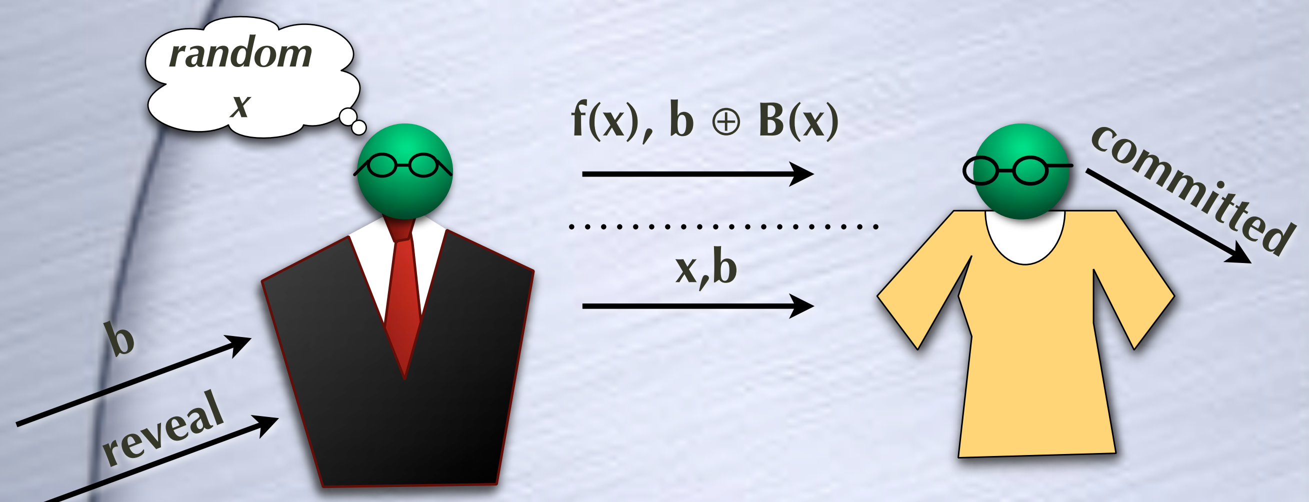

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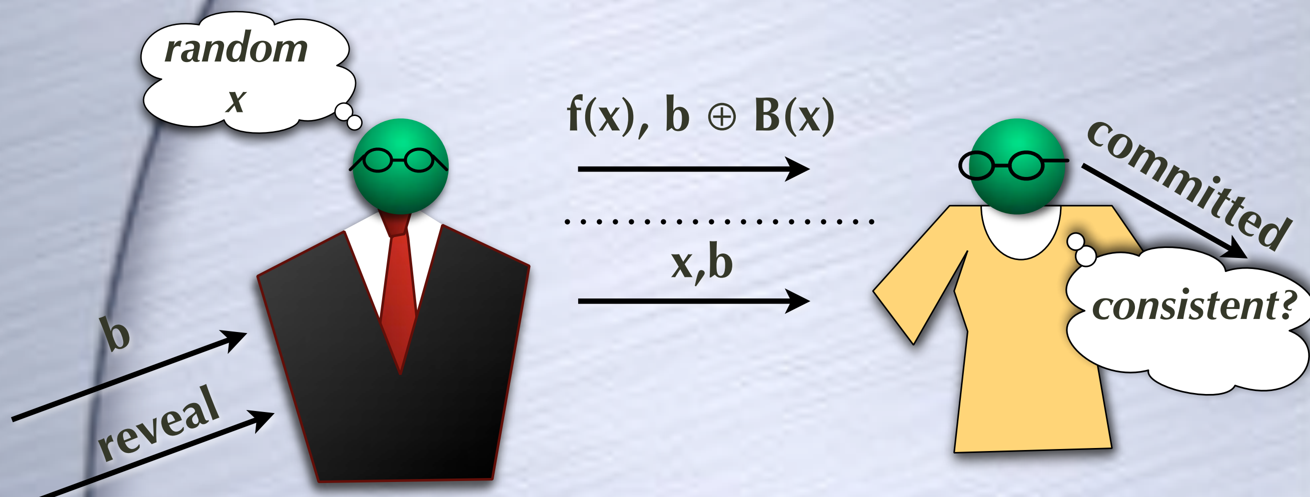

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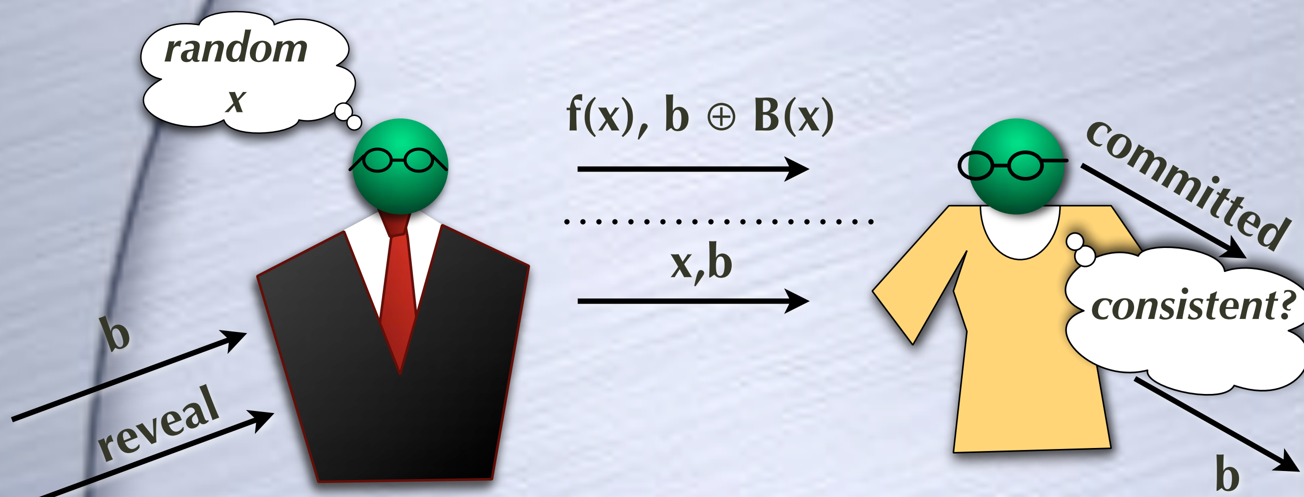

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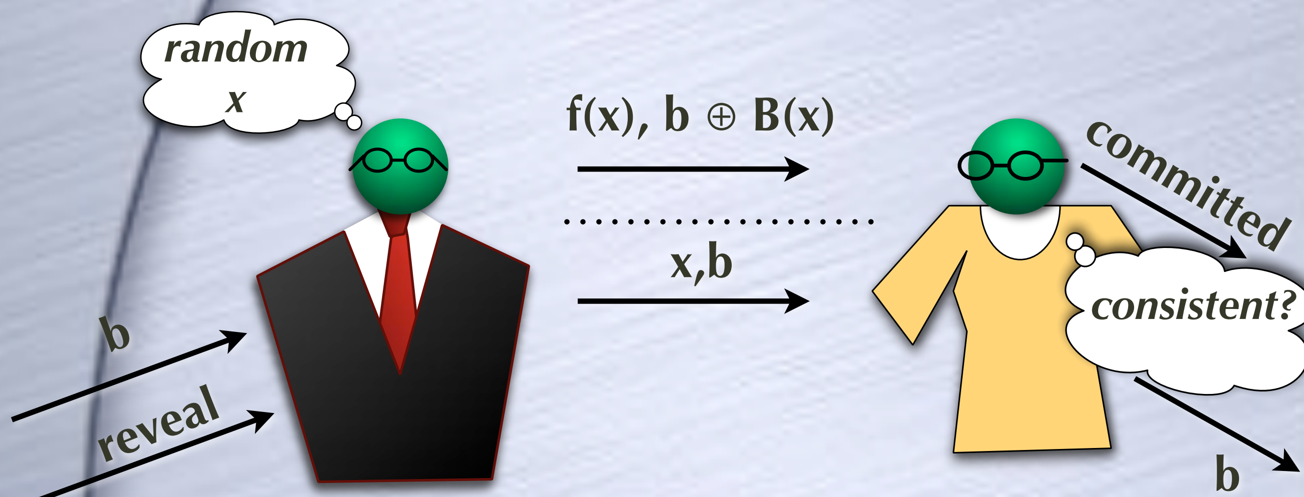

A Commitment Protocol

- Uses a OWP f and a hardcore predicate for it B
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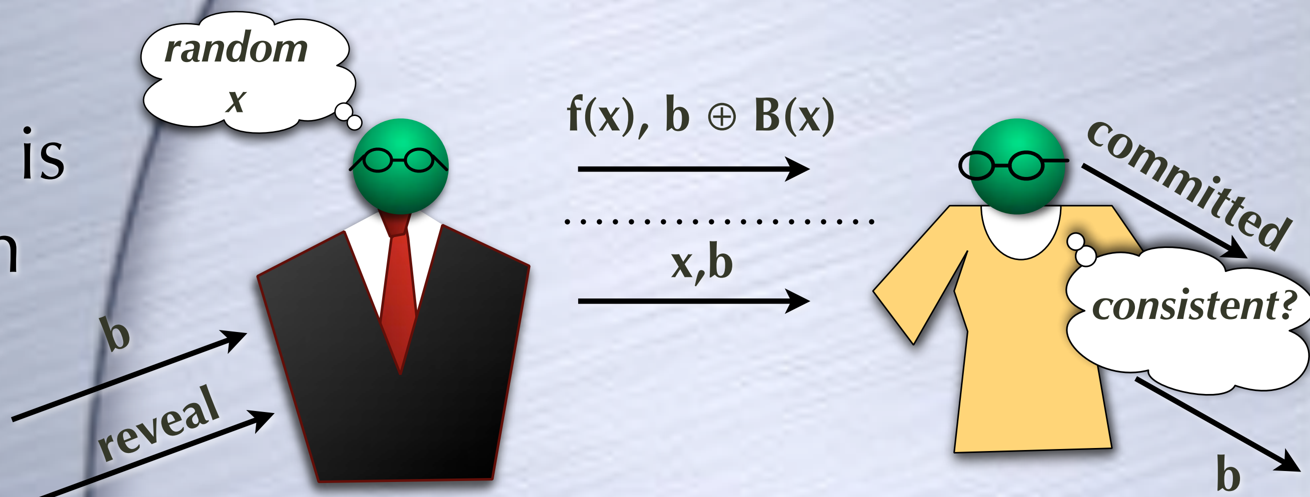
- Perfectly binding because f is a permutation
- Hiding because B(x) is pseudorandom given f(x)



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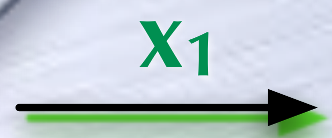

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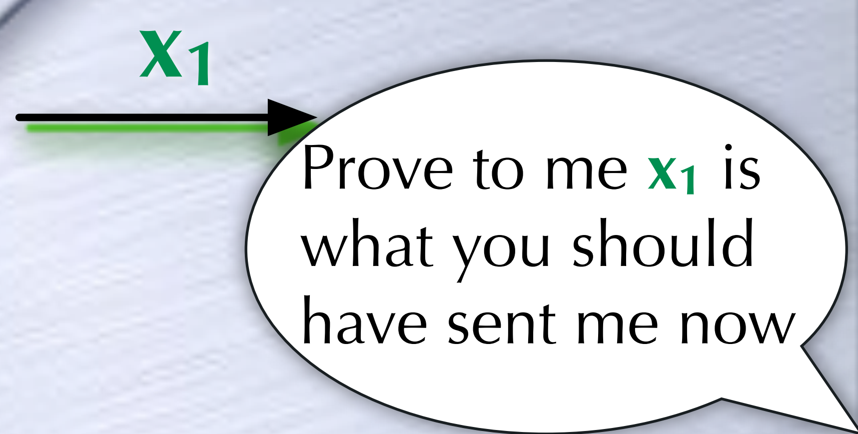

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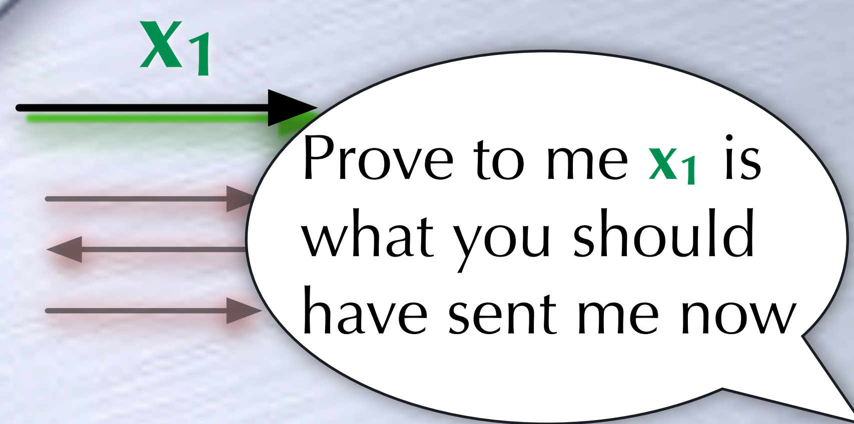

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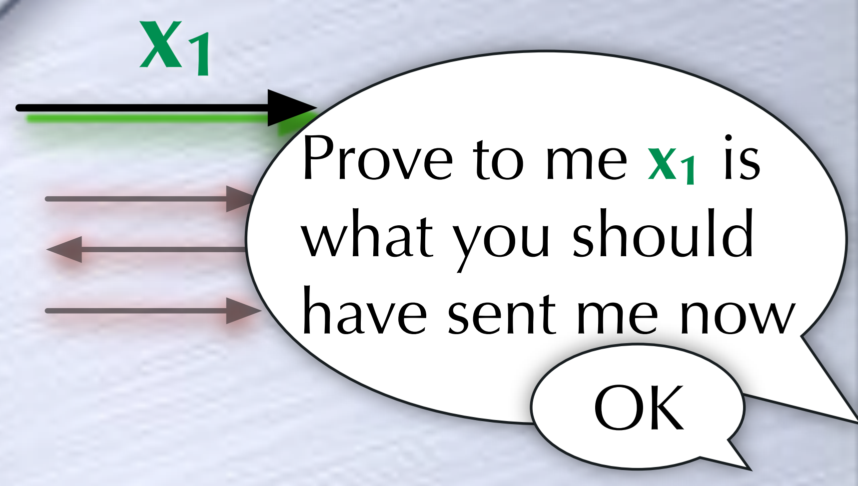

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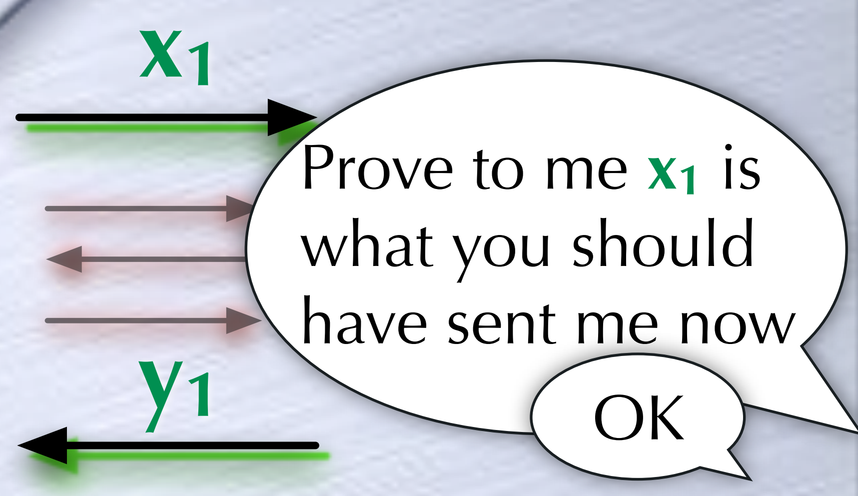

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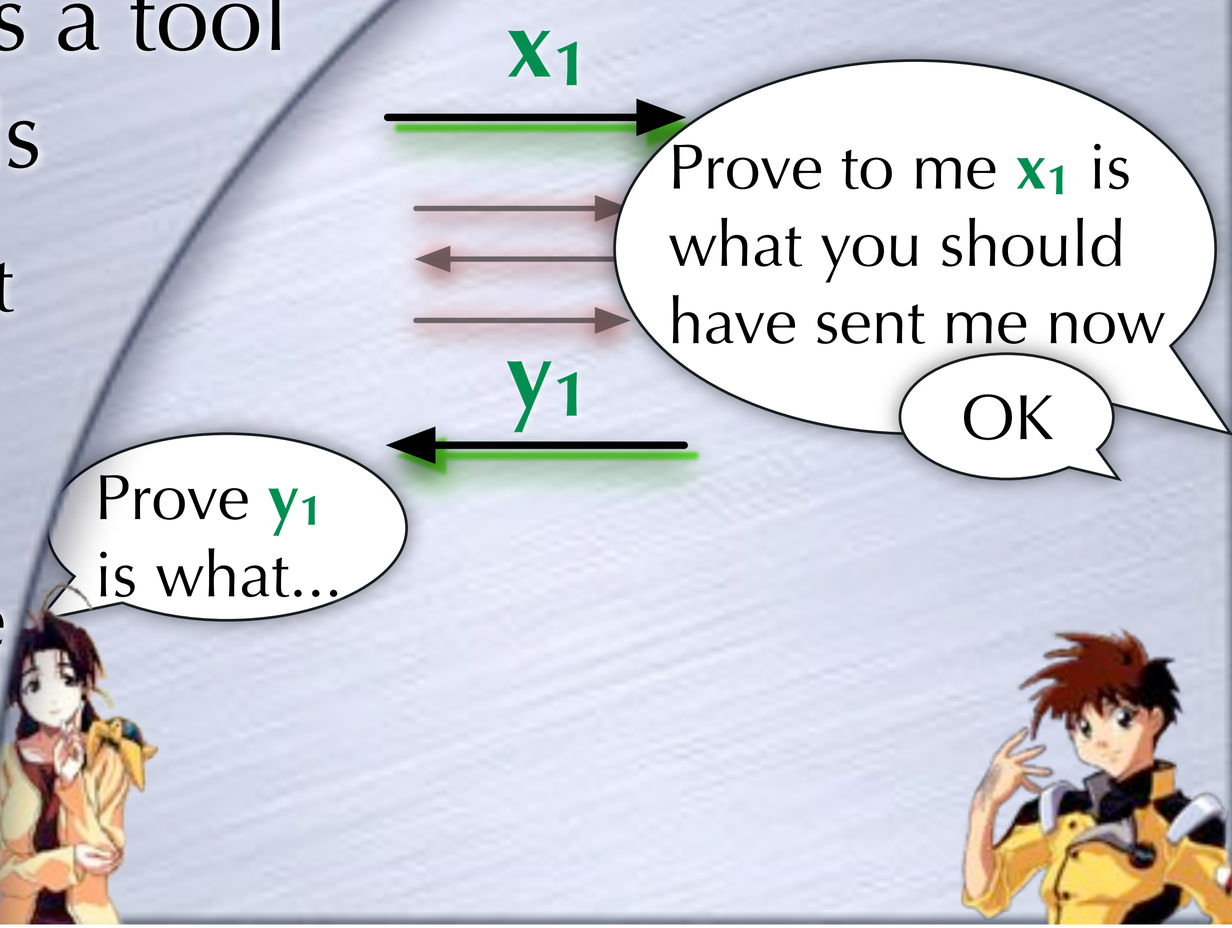

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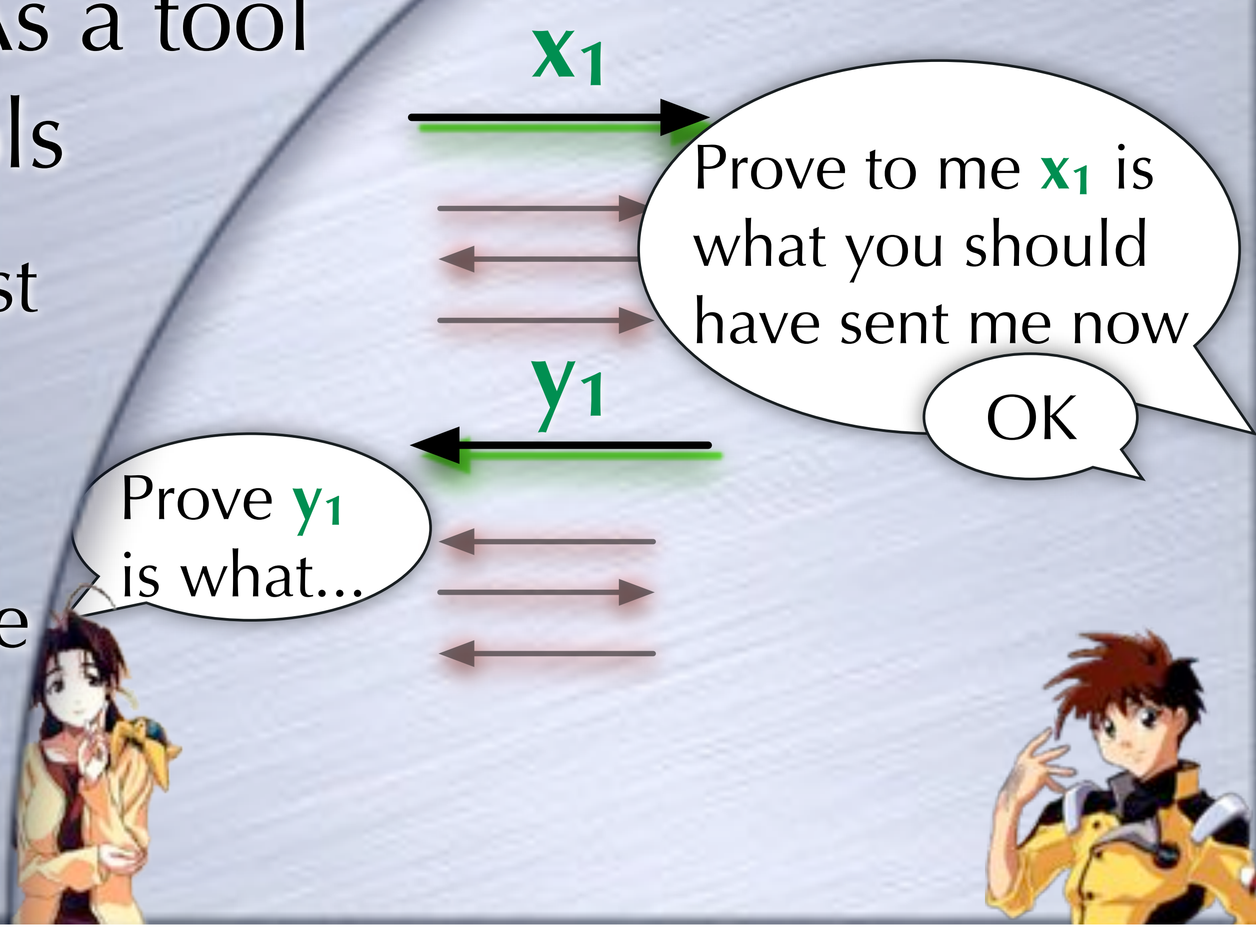

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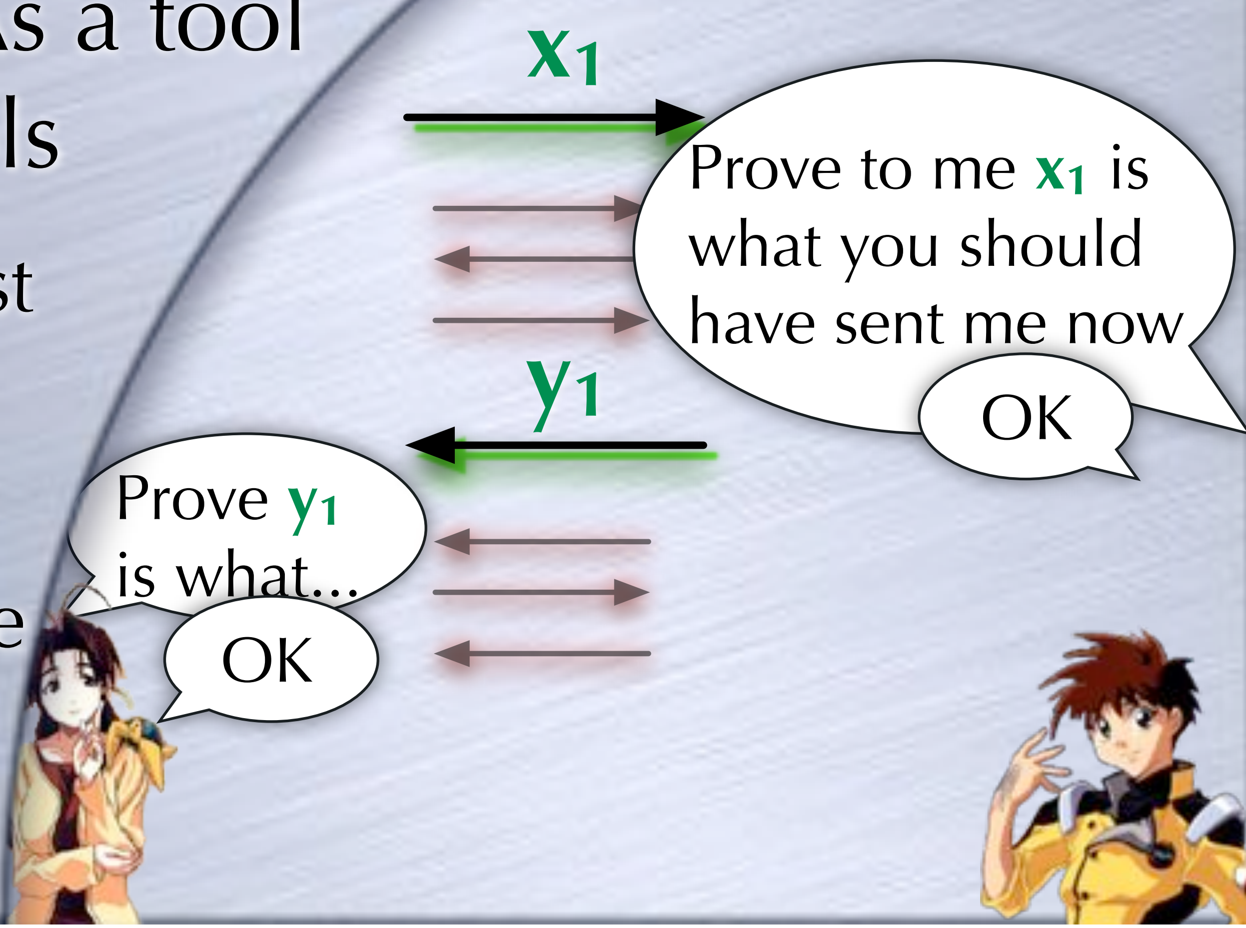

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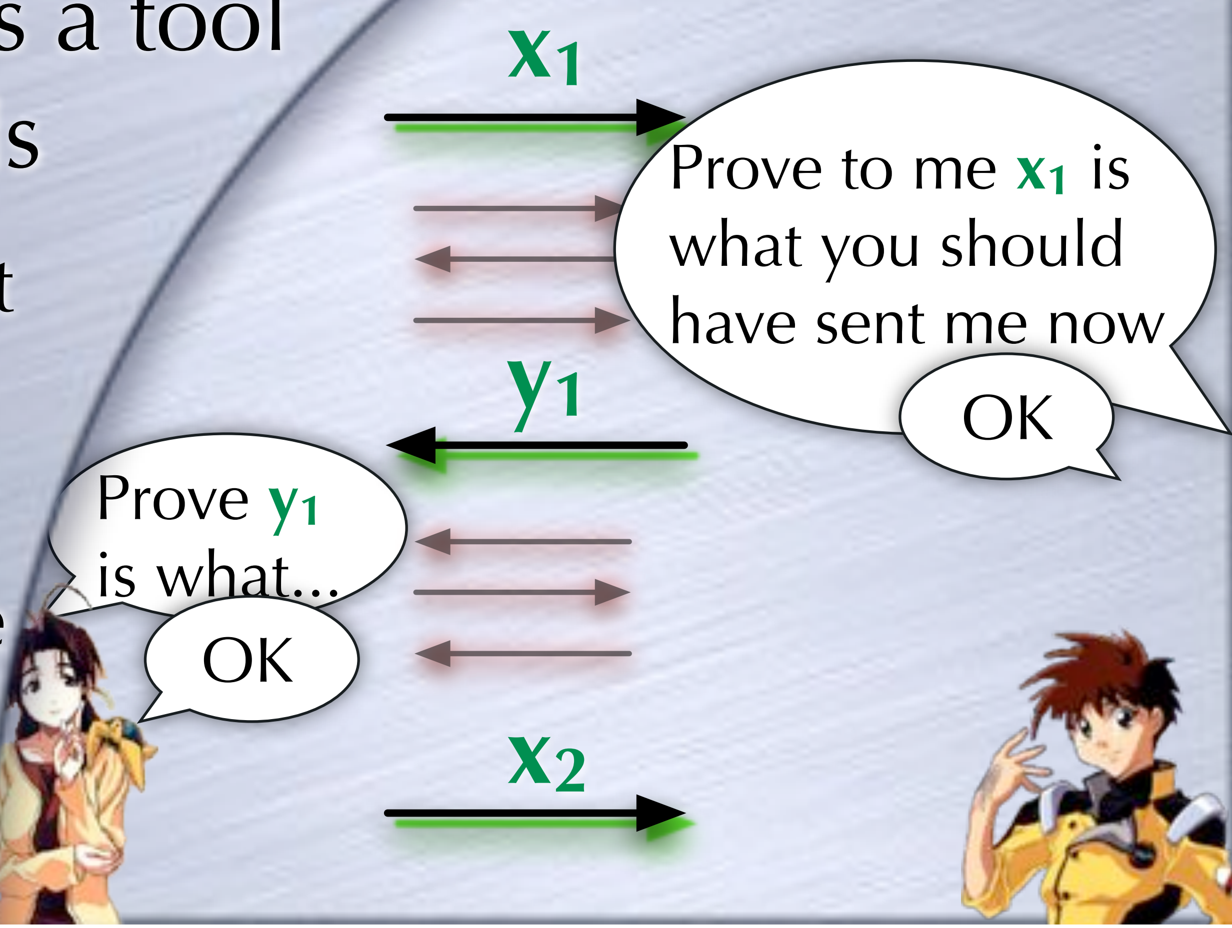

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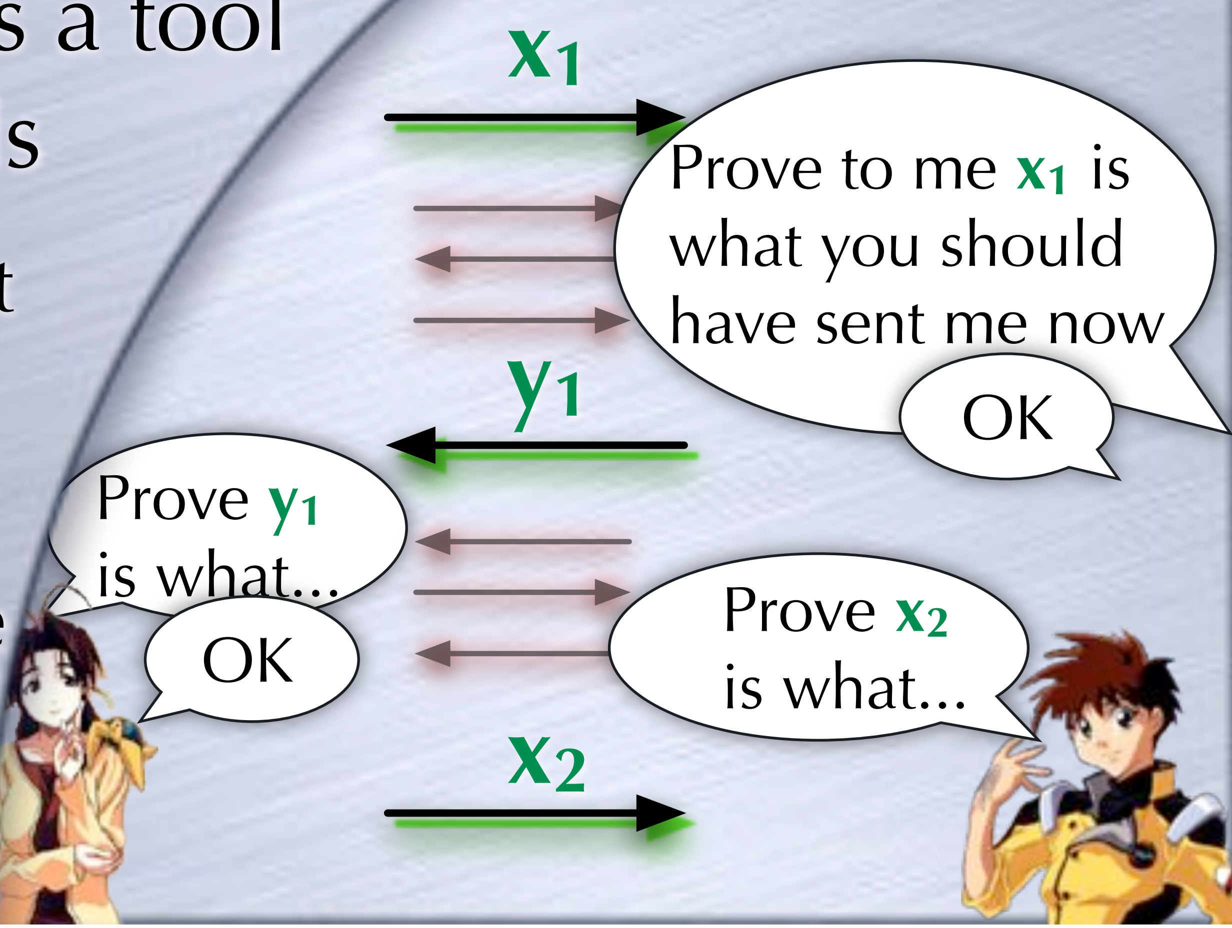

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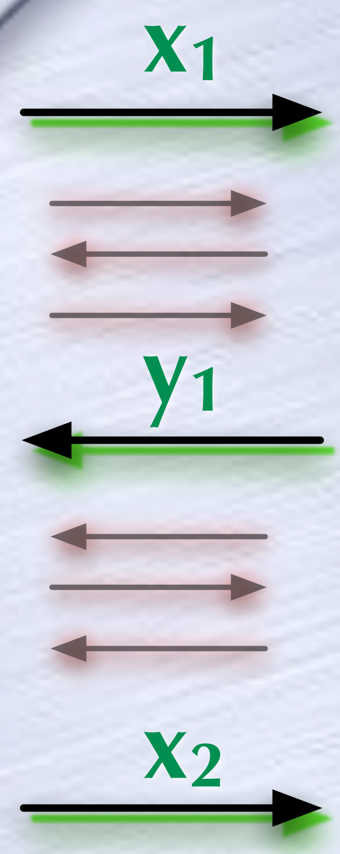

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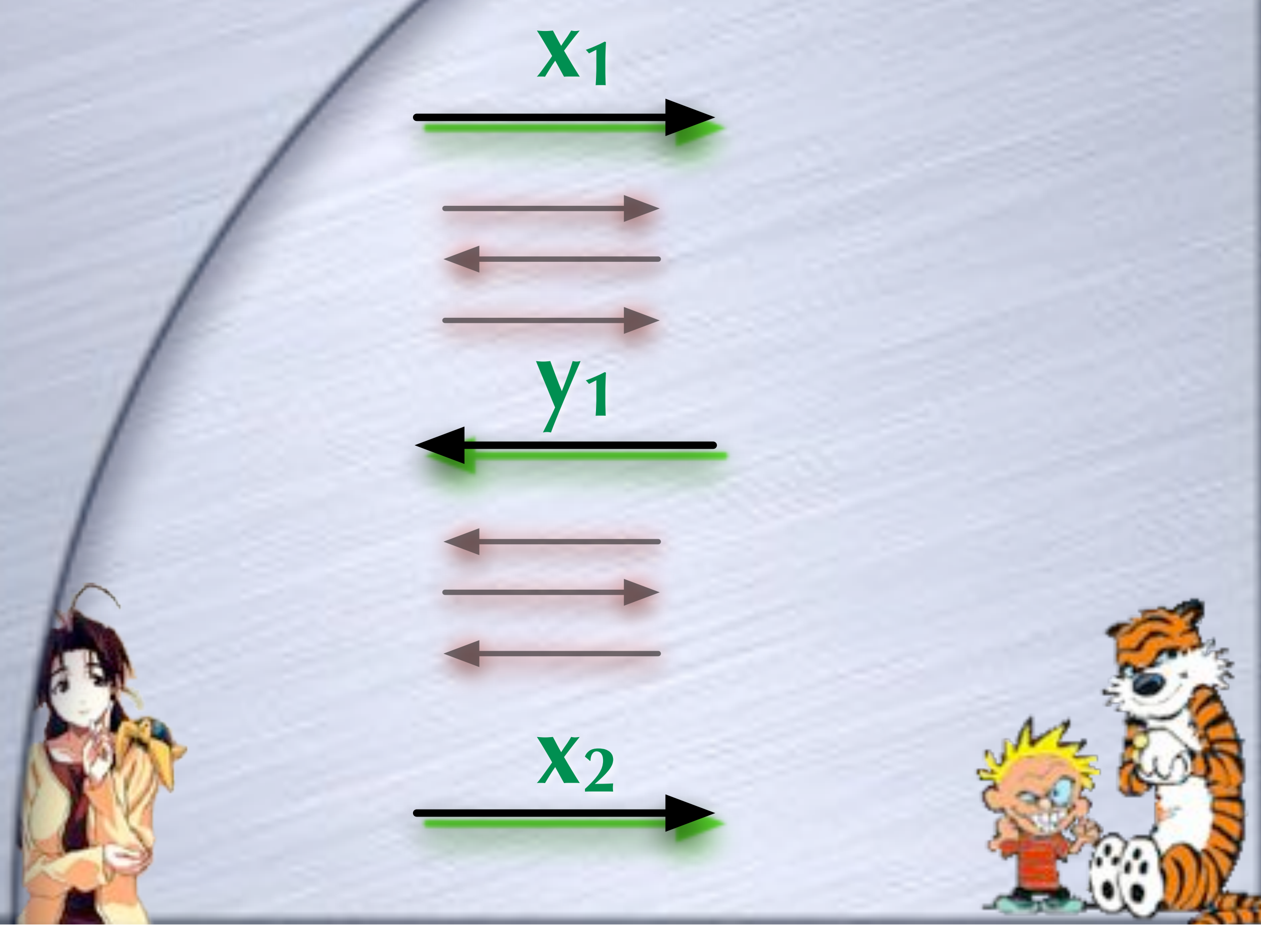

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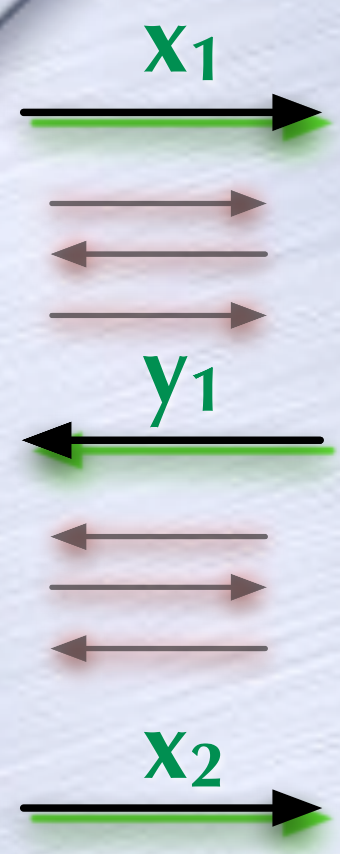

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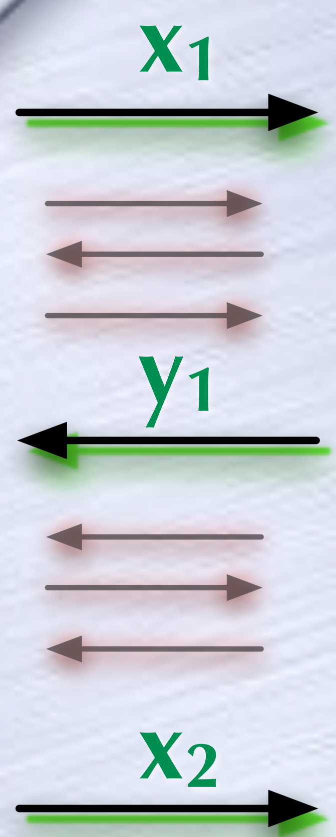

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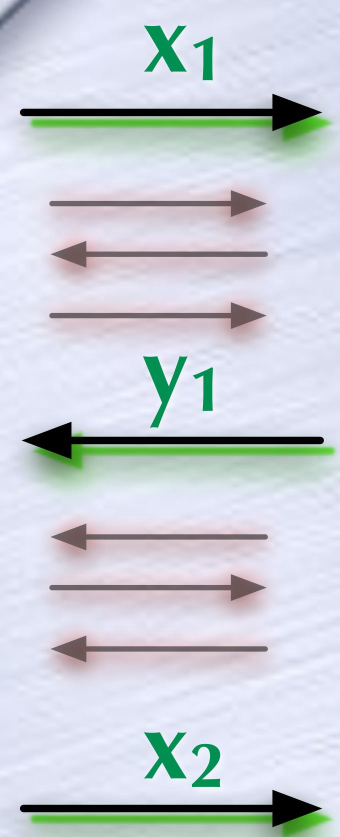
  - In general, to allow composition more complicated protocols



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- Defined in standalone setting, but WI property is preserved under "parallel composition"

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  - Also can NIZK-ify some ZK protocols in the RO Model (no CRS)

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- Some variants (NIZK, WI)