Separating Verifiable Delay Functions and Time-Lock Puzzles

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Joint work with Hamza Abusalah‡, Karen Azari* and Chethan Kamath†

*Uni Vienna
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Main Result

Theorem 1 (Main Result)

1. *Verifiable Delay Functions do not fully black-box imply Time-Lock Puzzles.*
2. *Time-Lock Puzzles do not fully black-box imply Verifiable Delay Functions.*

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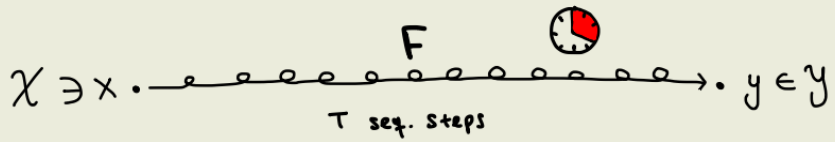
2. Short excourse on black-box reductions
3. Proof strategy

Verifiable Delay Functions (VDFs)

A *Verifiable Delay Function* is

- a delay function $F\colon \mathcal{X} \to \mathcal{Y}$



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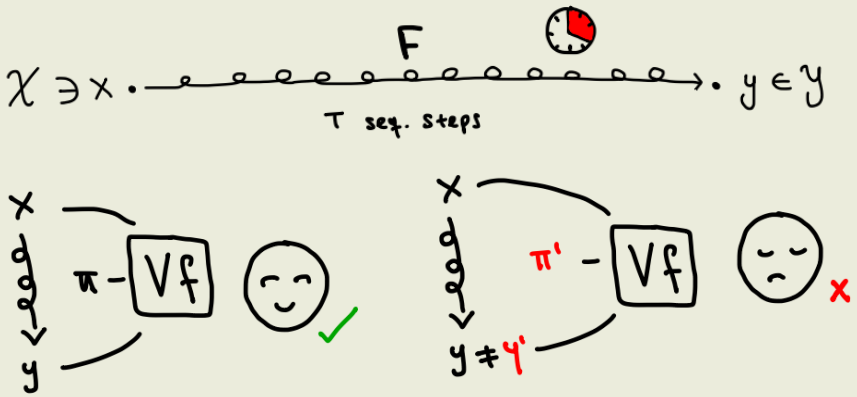

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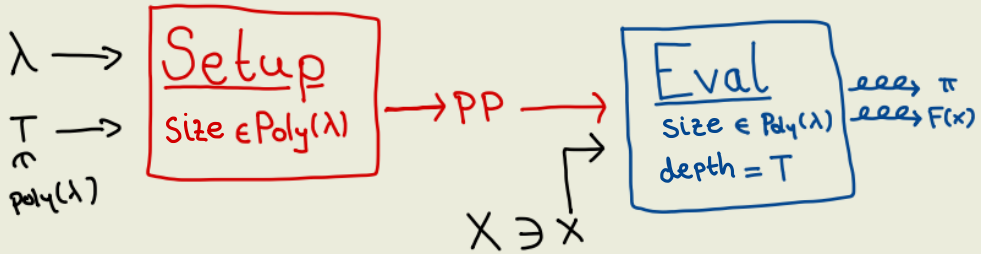

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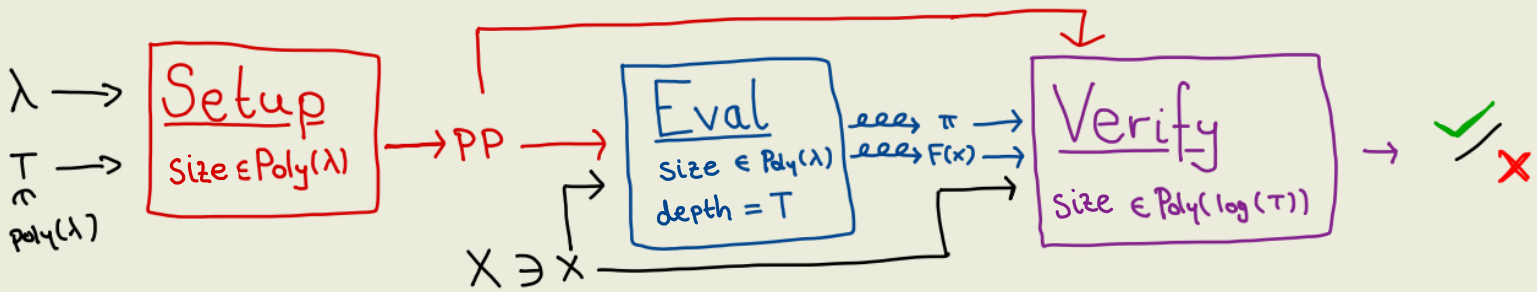

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Soundness: given (pp, x), no PPT adversary can find (y', π') s.t. $y' \neq F(x)$ and $\mathsf{Verify}(\mathsf{pp}, x, y', \pi') = 1$.

Time-Lock Puzzles (TLPs)

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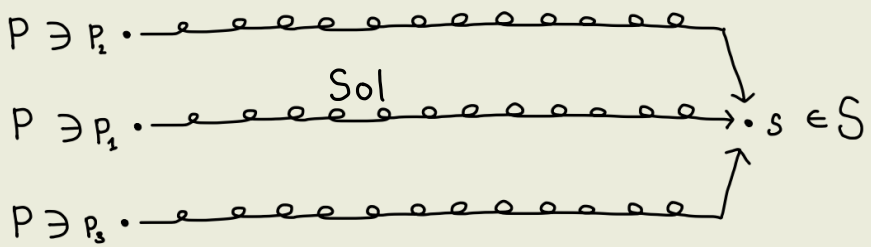

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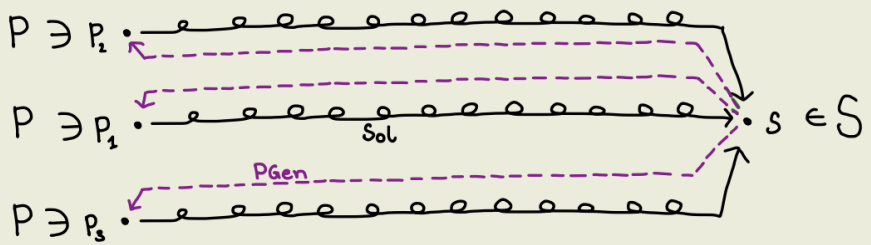

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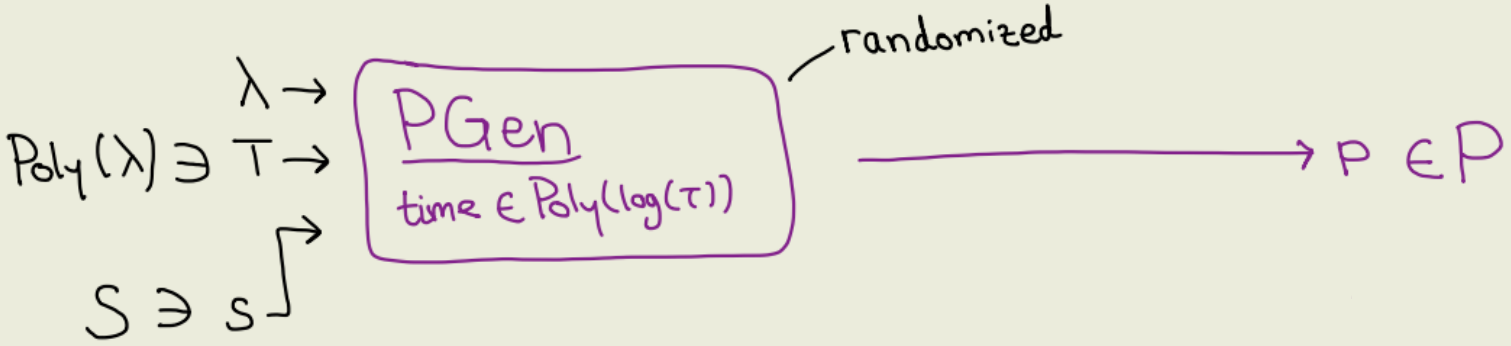

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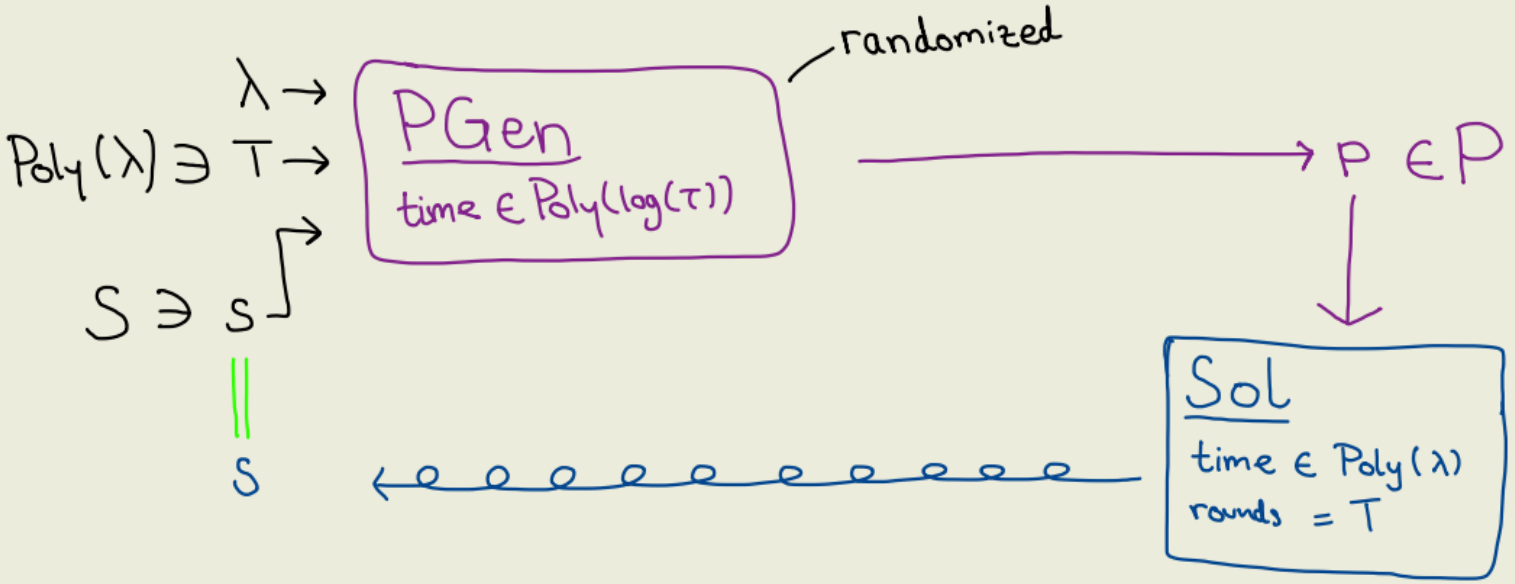

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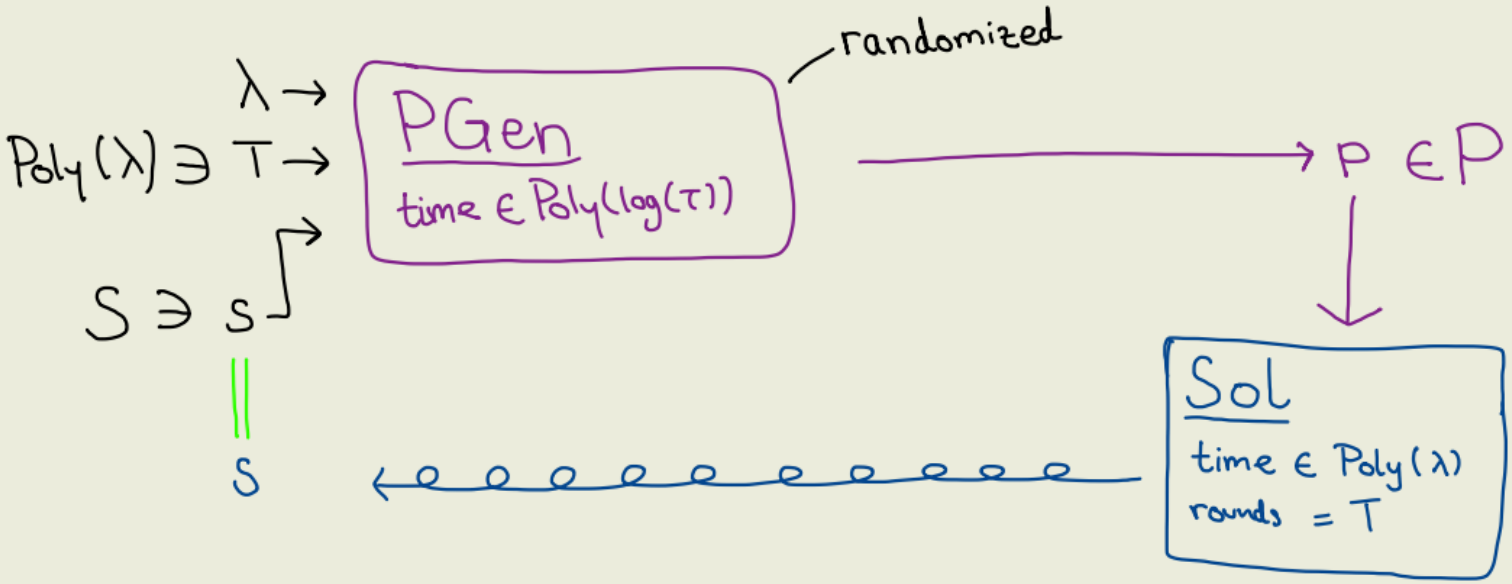

Indistinguishability of Puzzles. For any $s_0, s_1 \in \mathcal{S}$,
$\mathsf{PGen}(s_0, T) \approx_{\mathrm{depth} \ll T} \mathsf{PGen}(s_1, T)$

Known Implications

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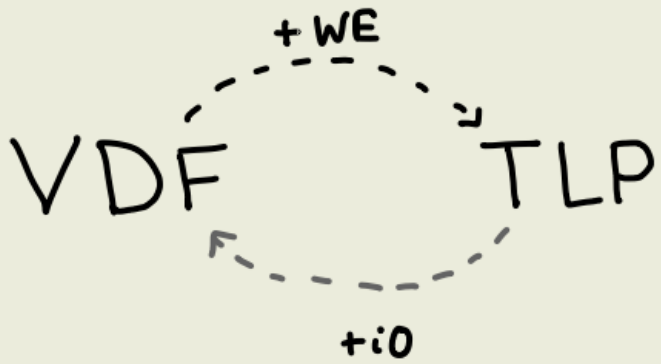

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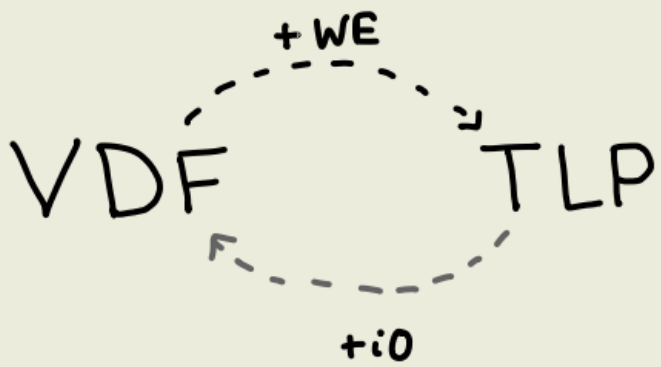

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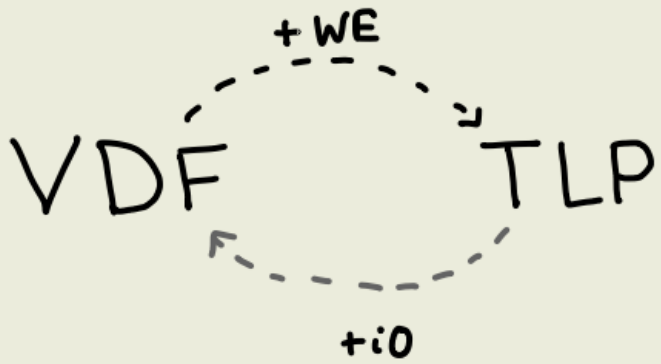

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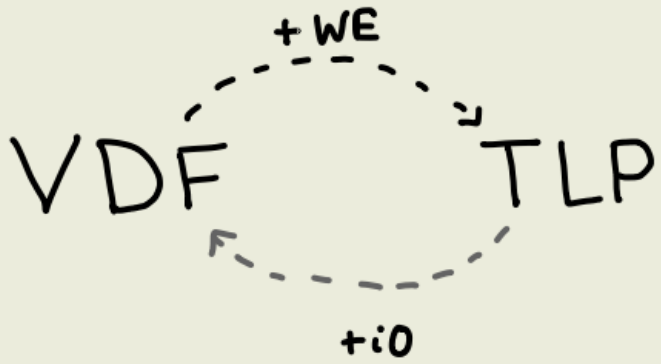

However, these constructions

- rely on additional assumptions
- are *not* black-box

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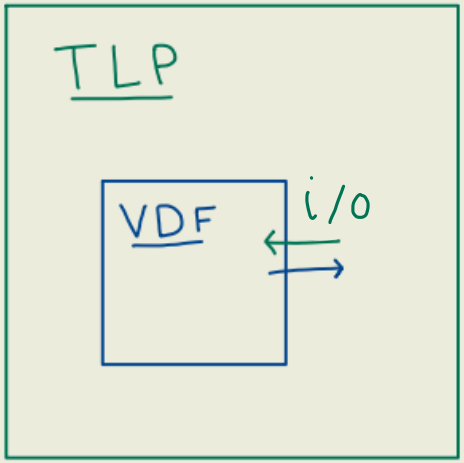

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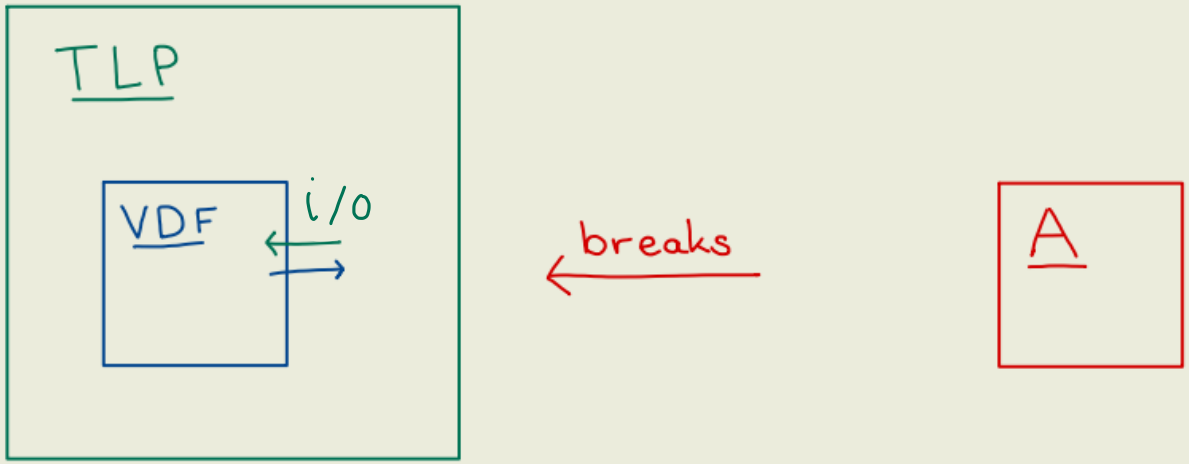

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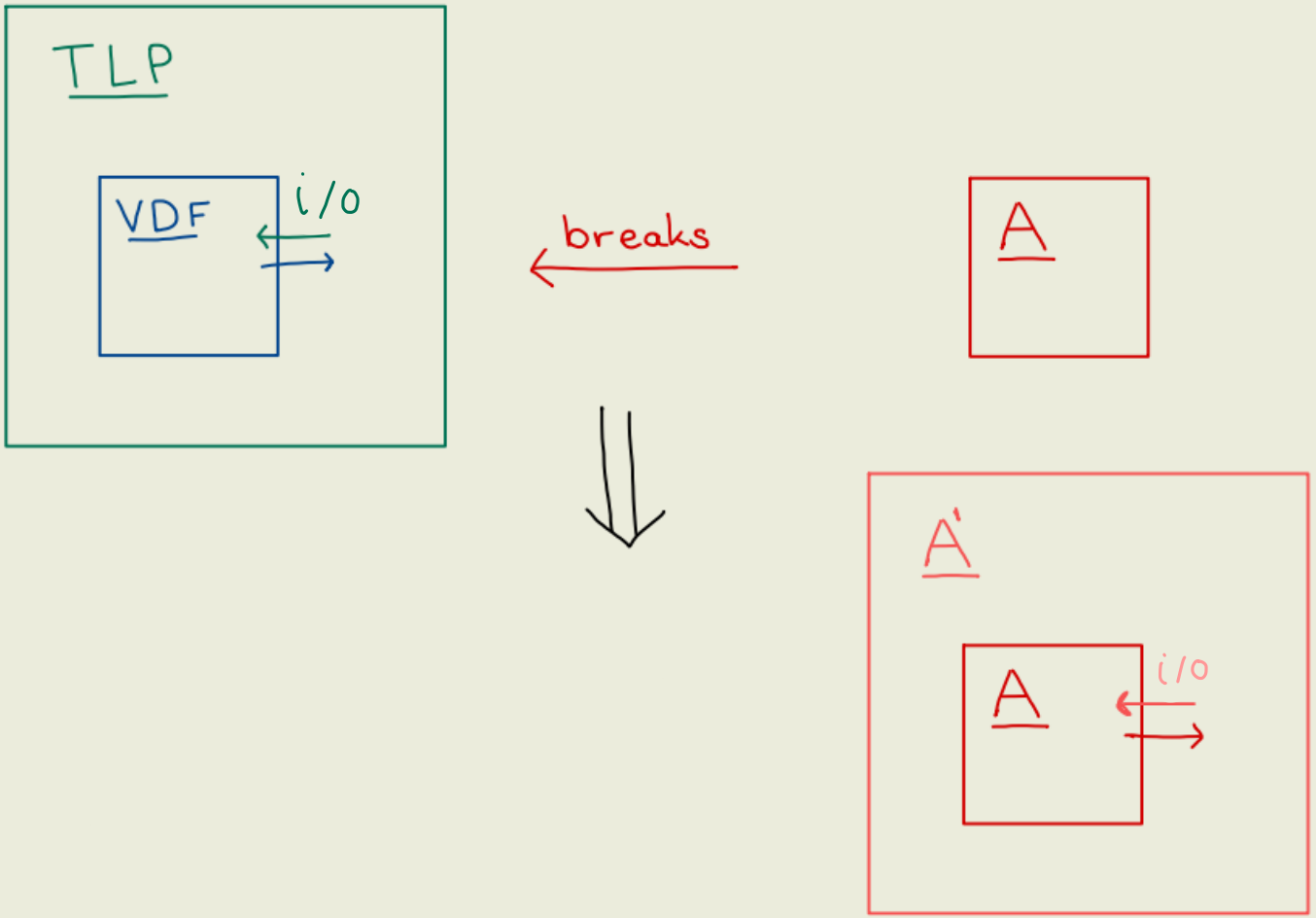

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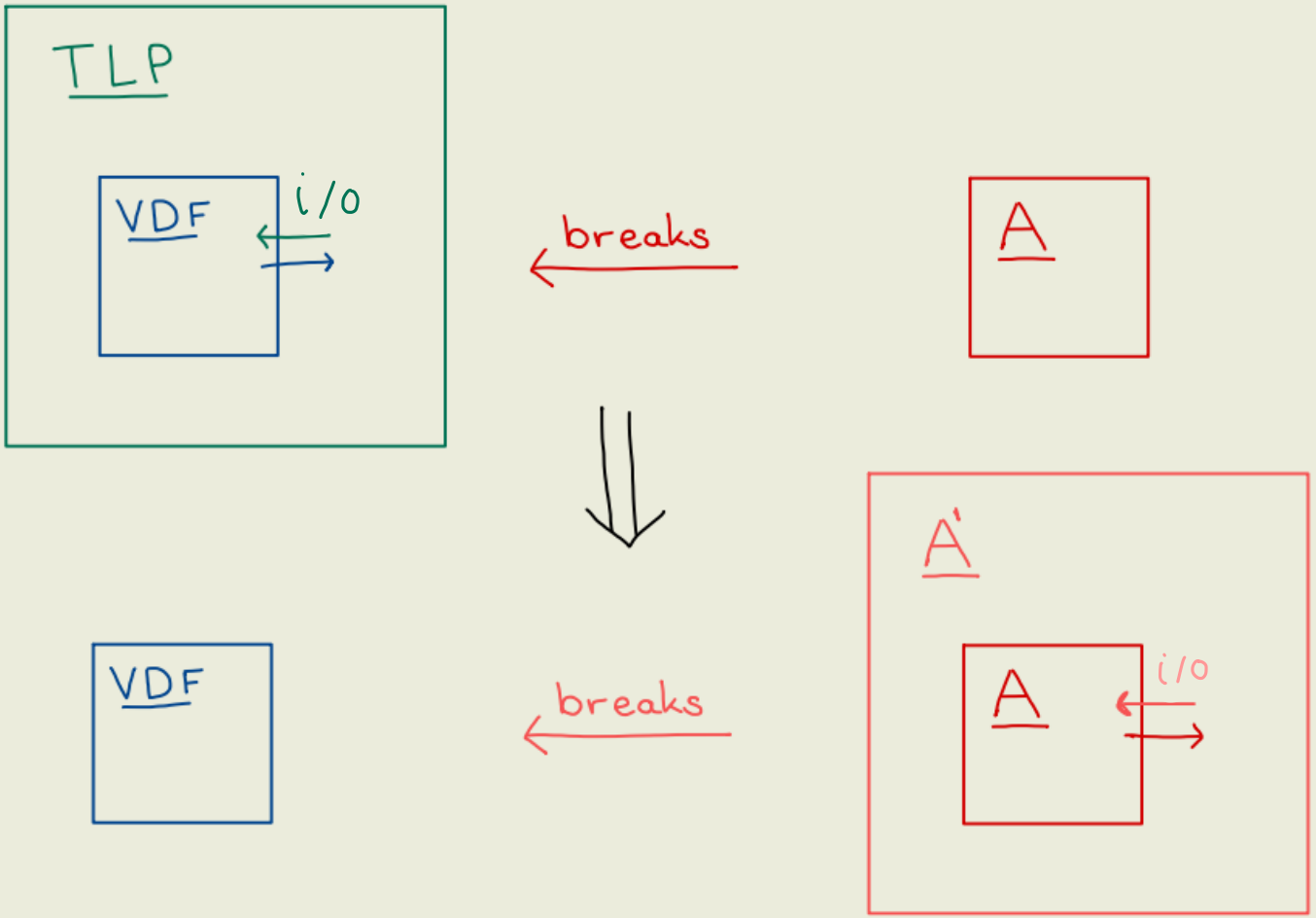

Ruling out Black-Box Reductions

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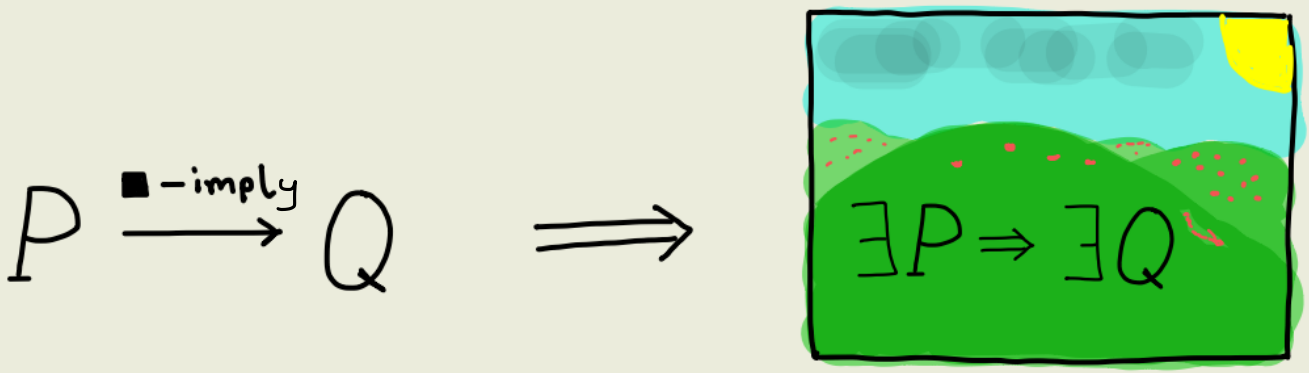
If P black-box implies Q, then in every "world" in which P exists, Q exists.



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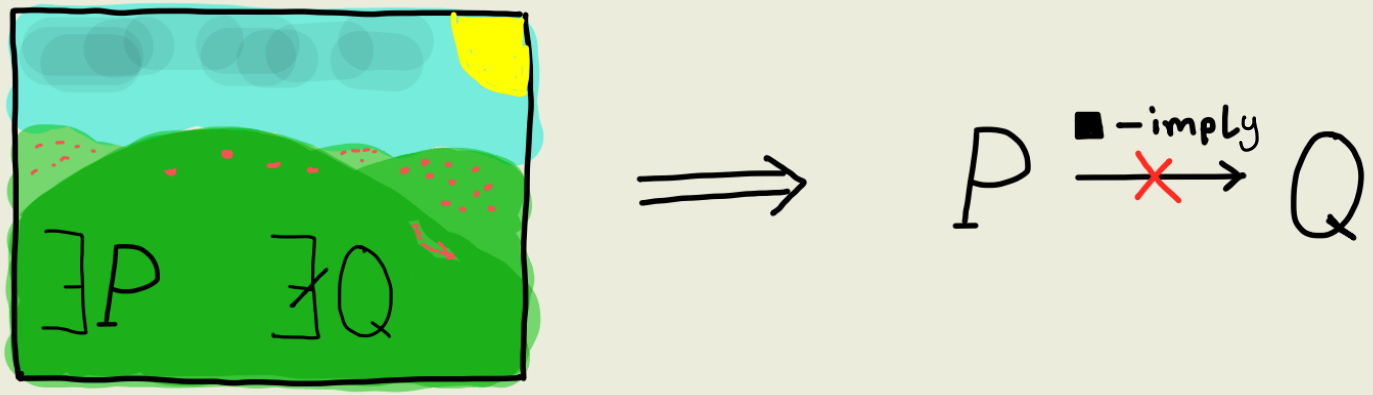

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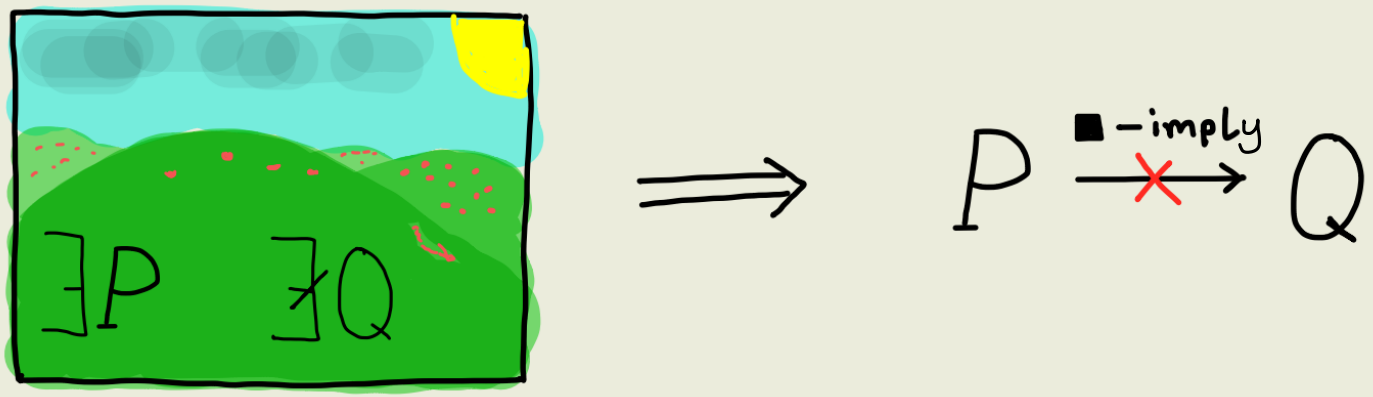

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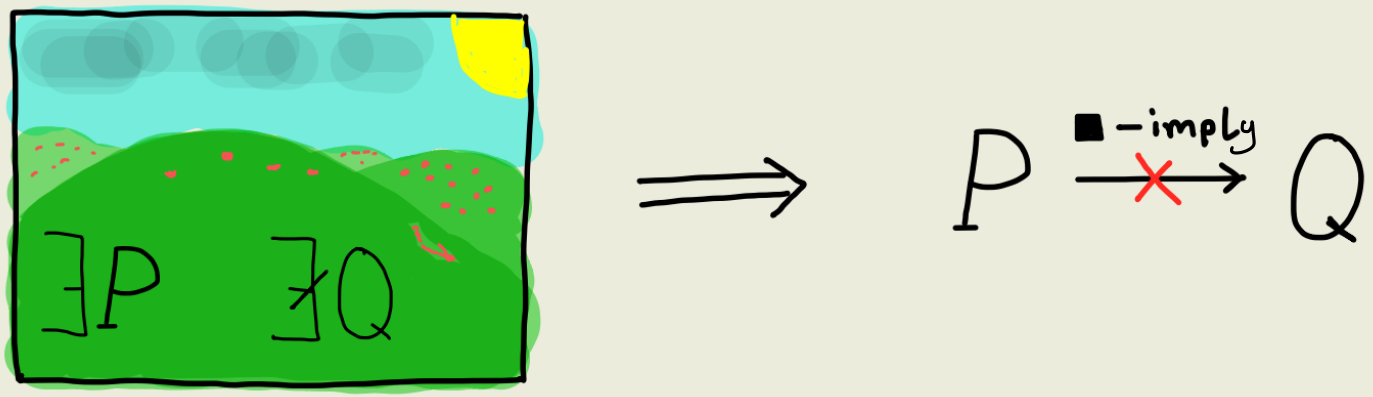

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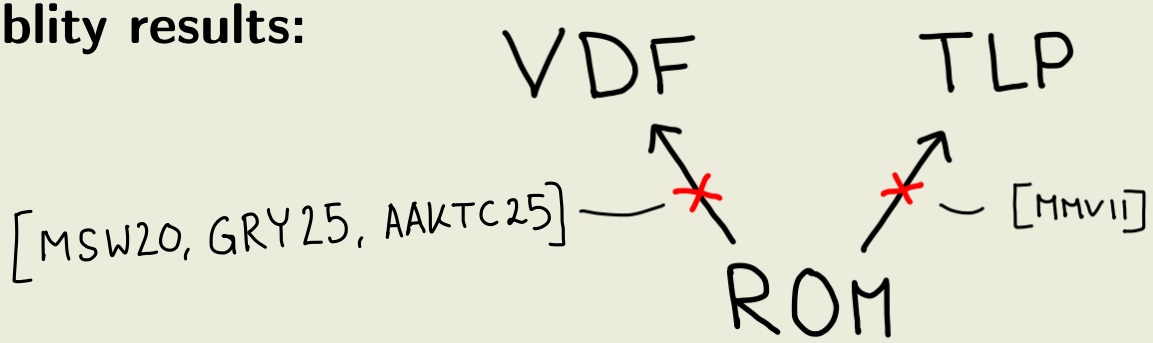

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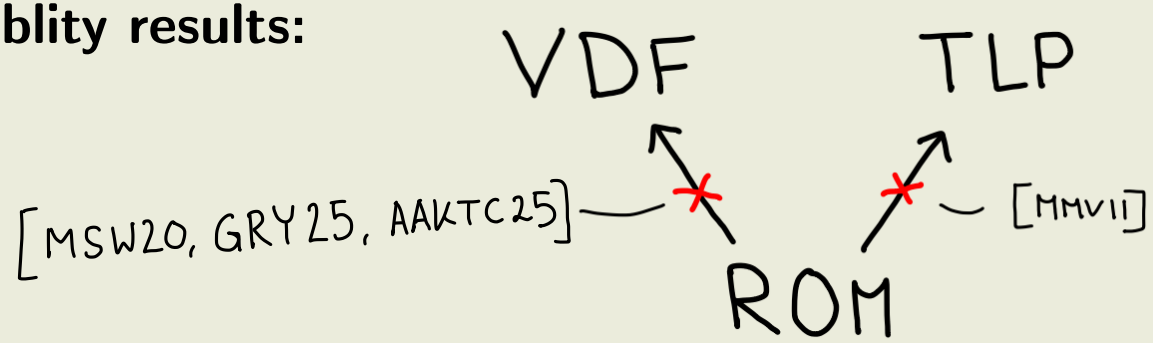

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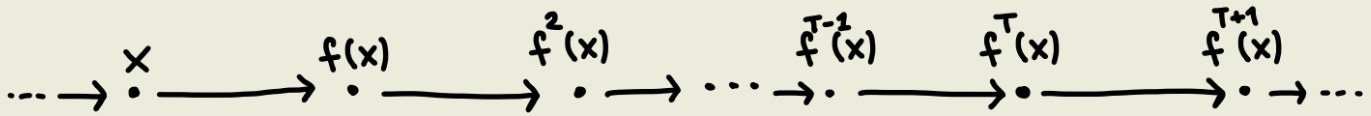

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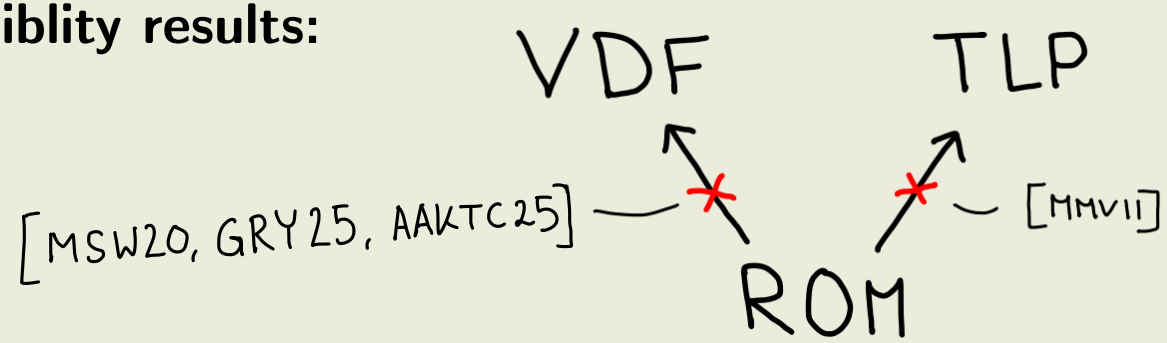

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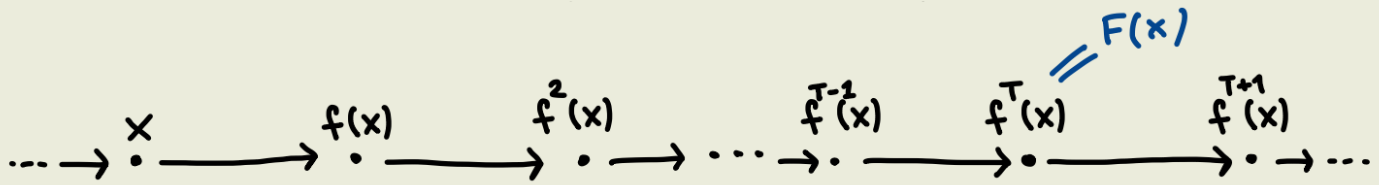

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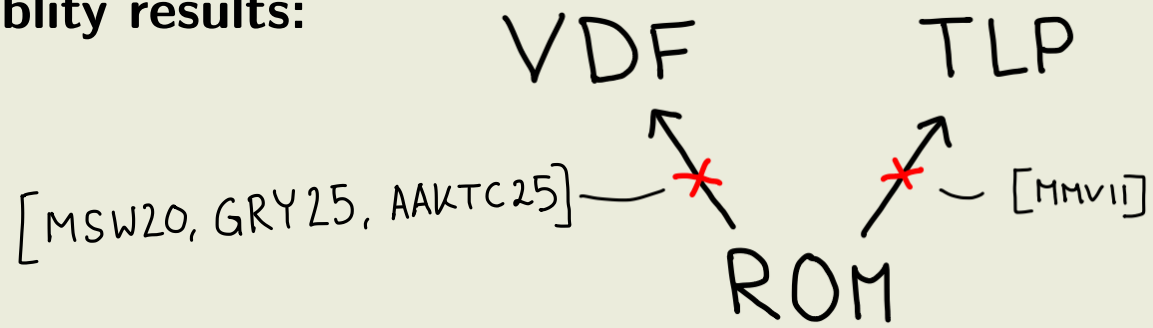

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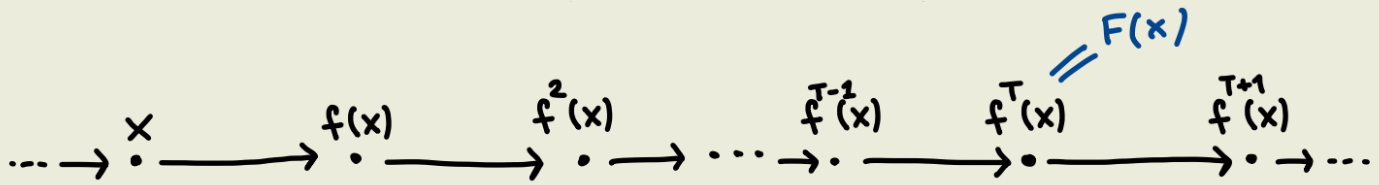

Idea: Extend the ROM with minimal additional oracles s.t. we can construct one of the two primitives, but (still) rule out the other.

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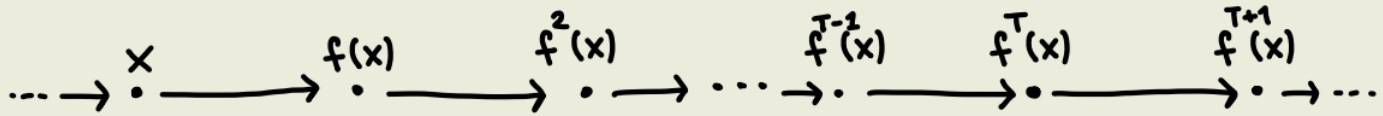

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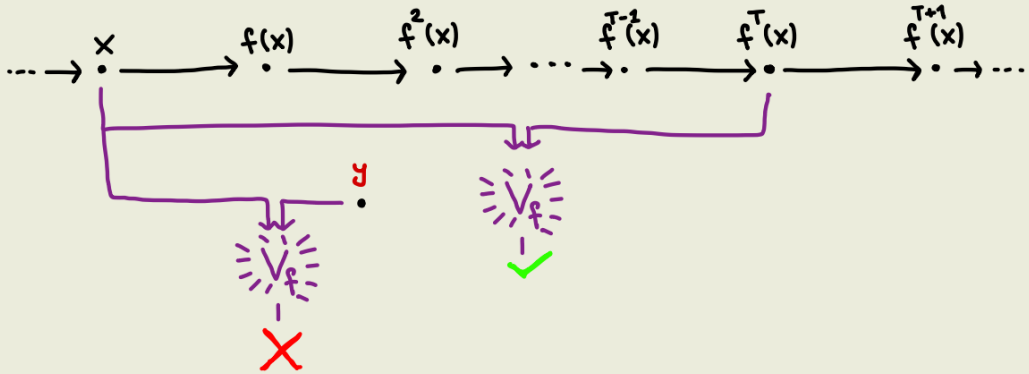

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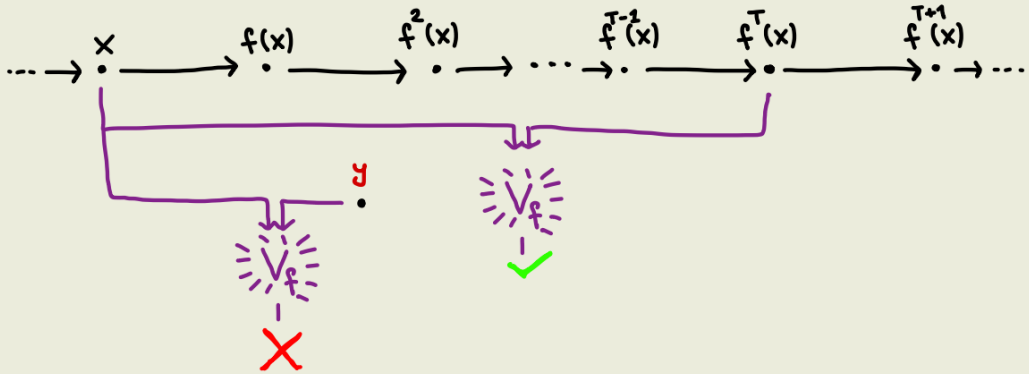

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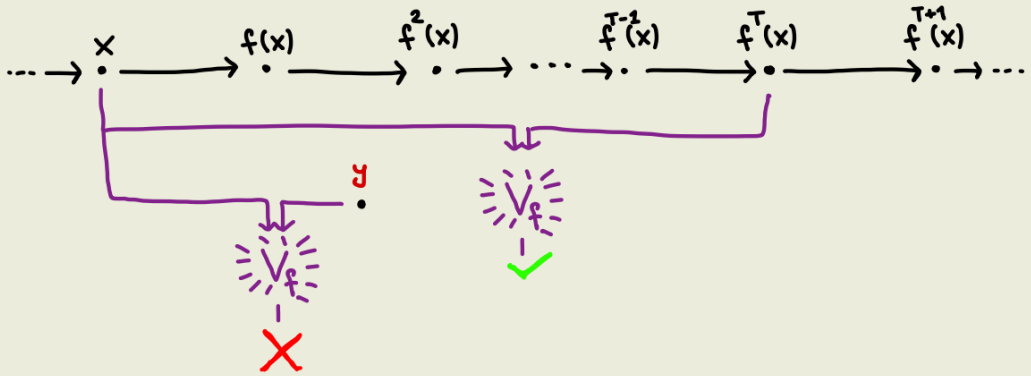

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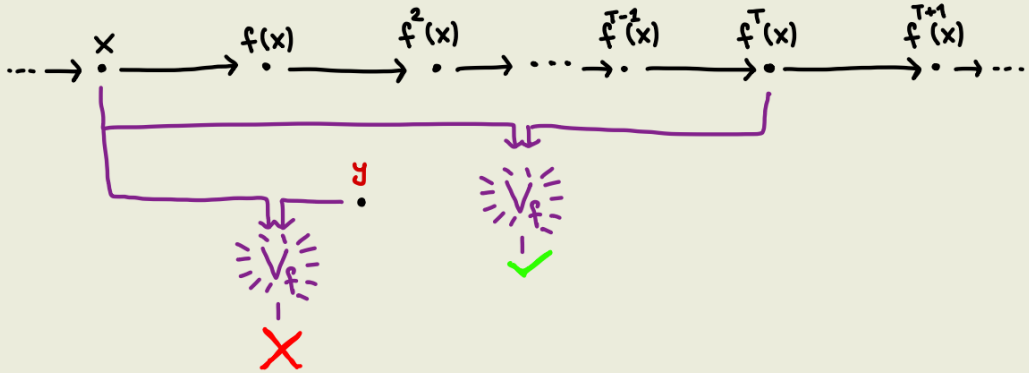

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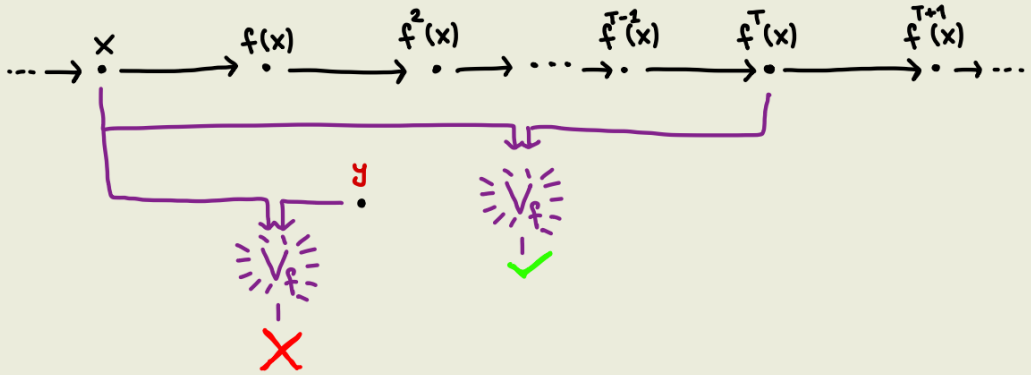

- Now:
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  - **Key Insight:** We show that given a TLP in this model we can construct a TLP in the plain ROM by simulting the verification oracle V_f using some extra queries.

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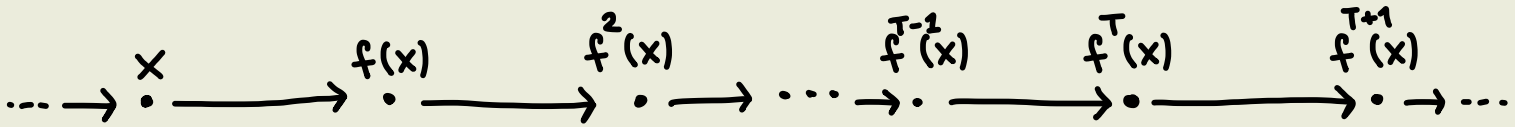

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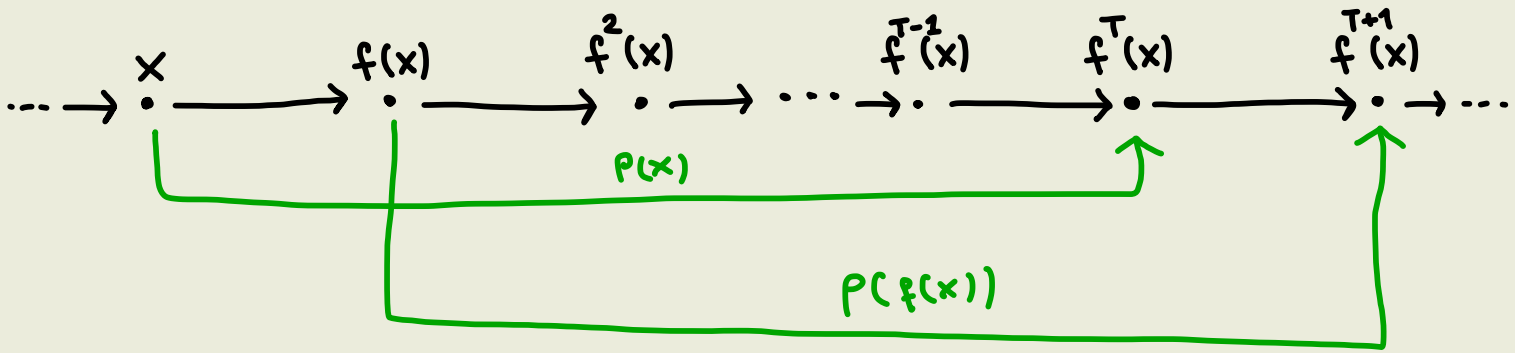
Naive Idea: Extend the ROM with "puzzle oracle": $\rho(x) := f^T(x)$.



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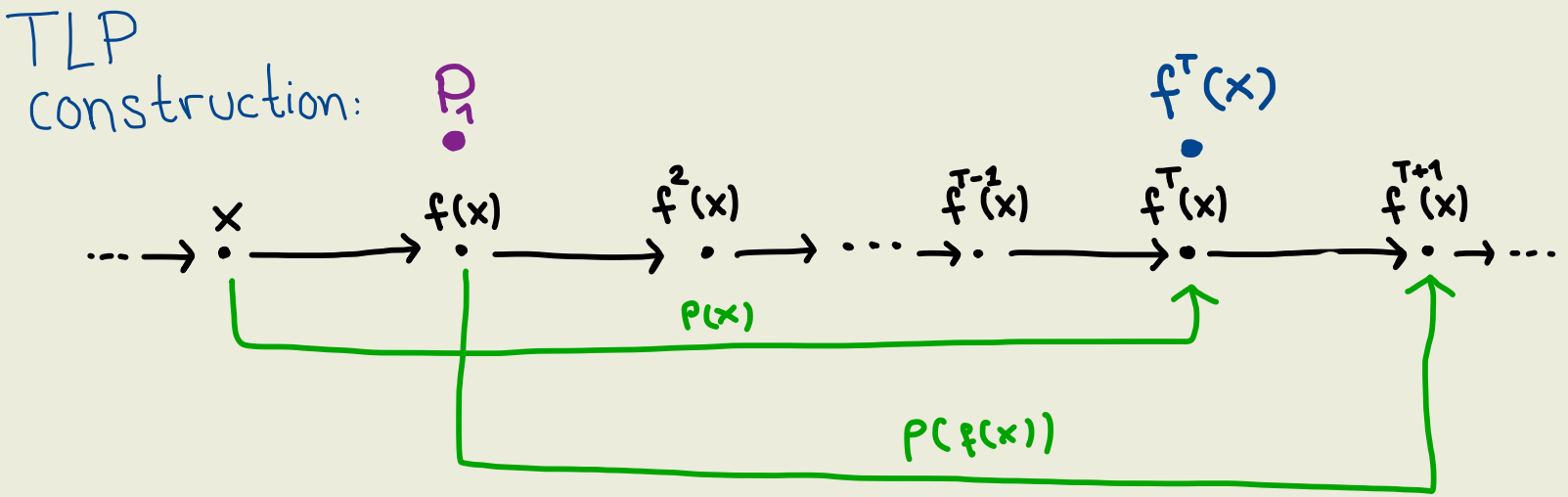

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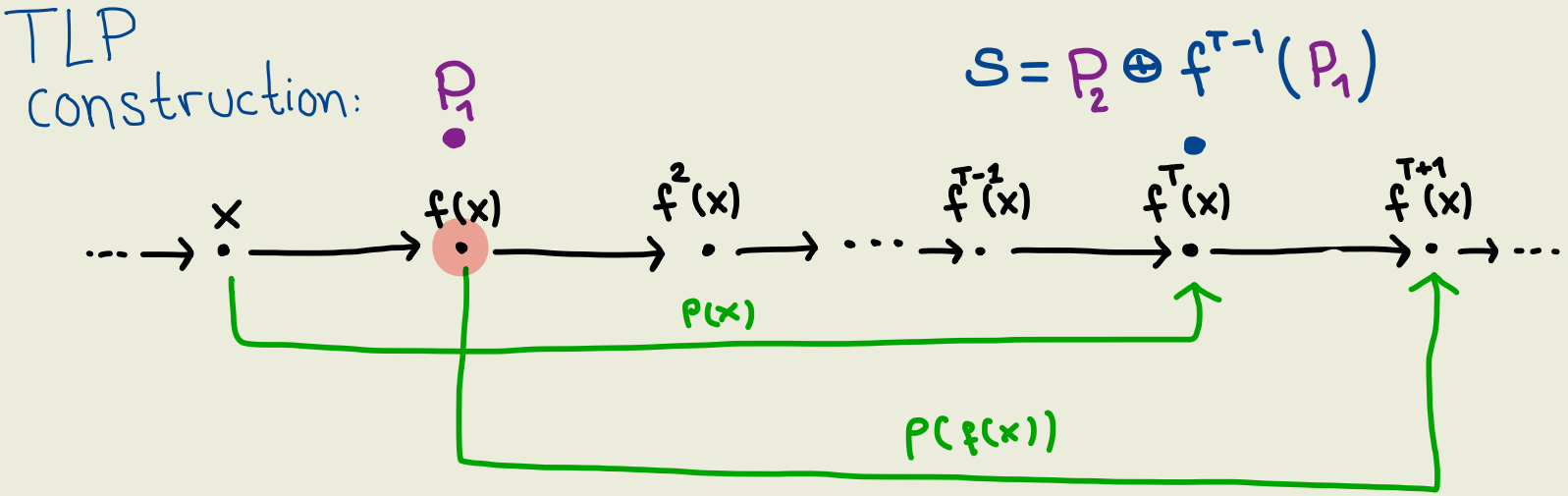

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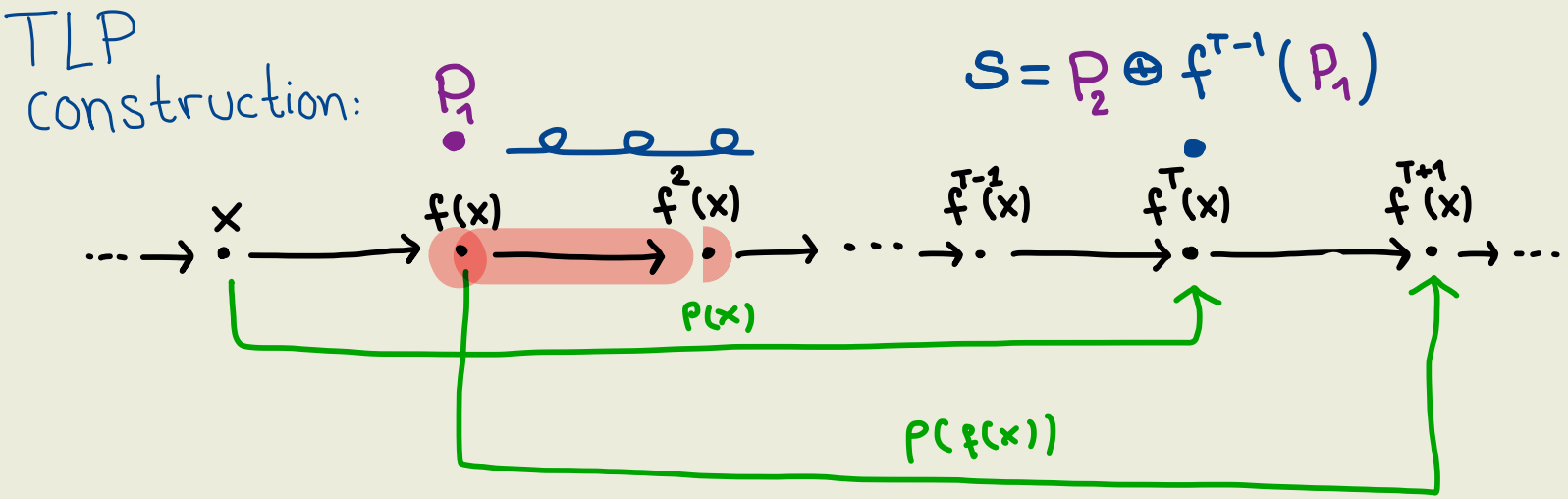

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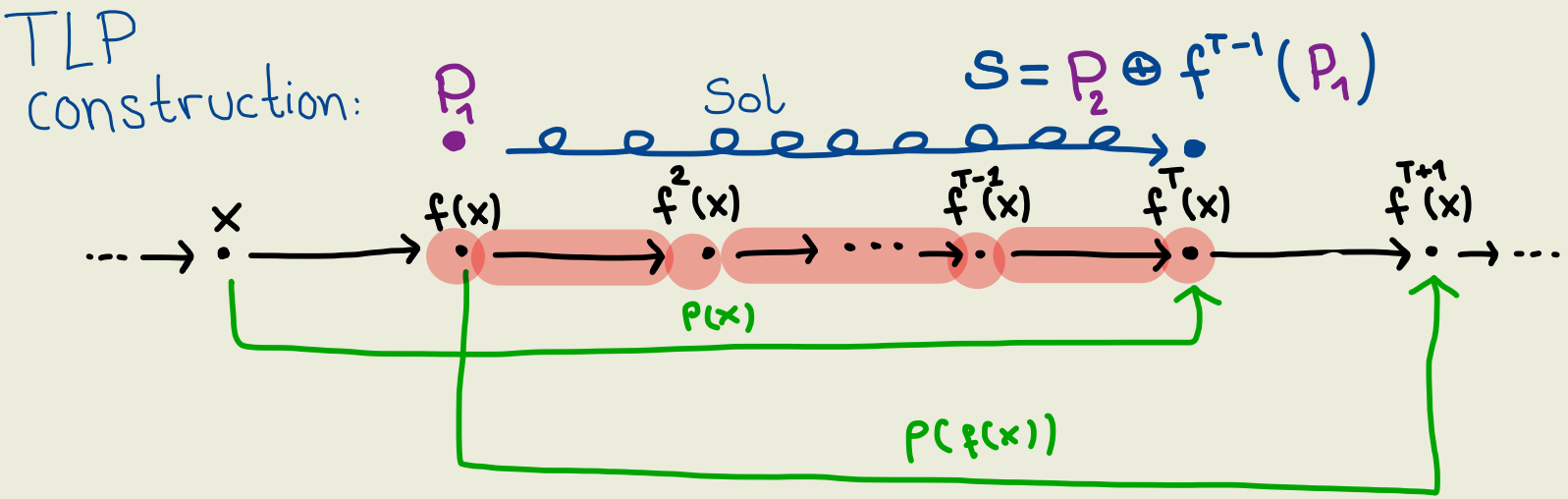

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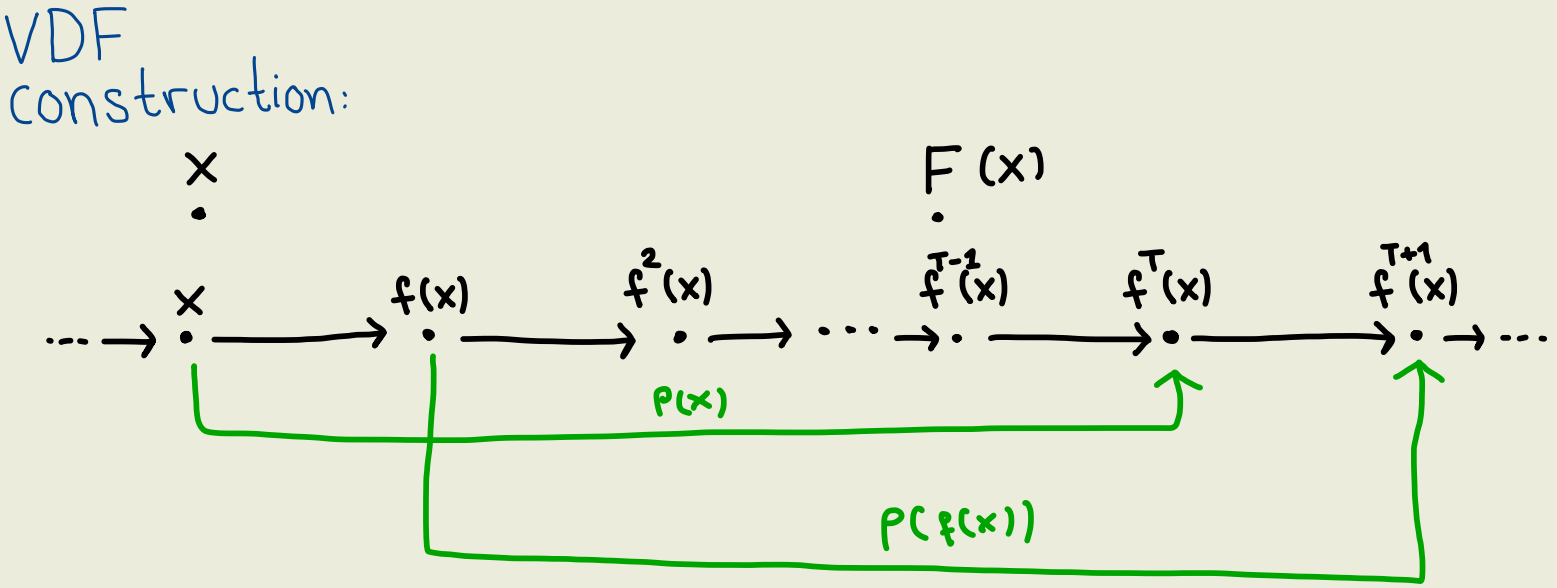

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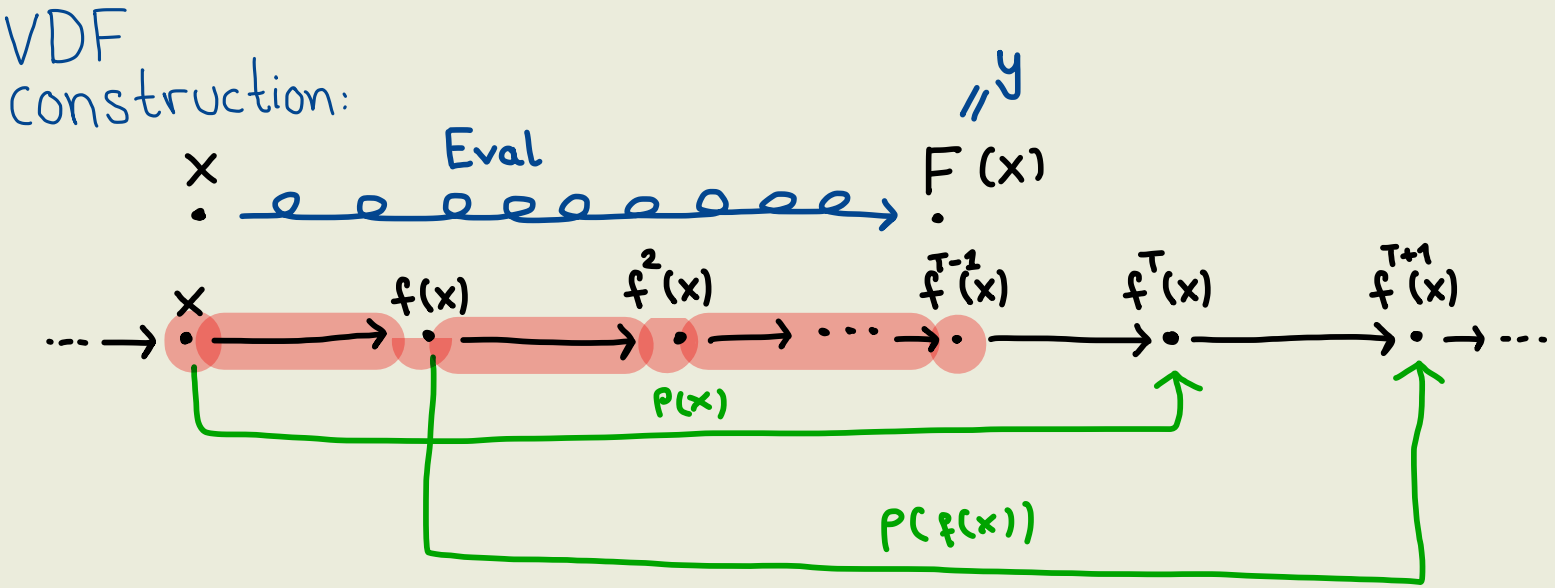

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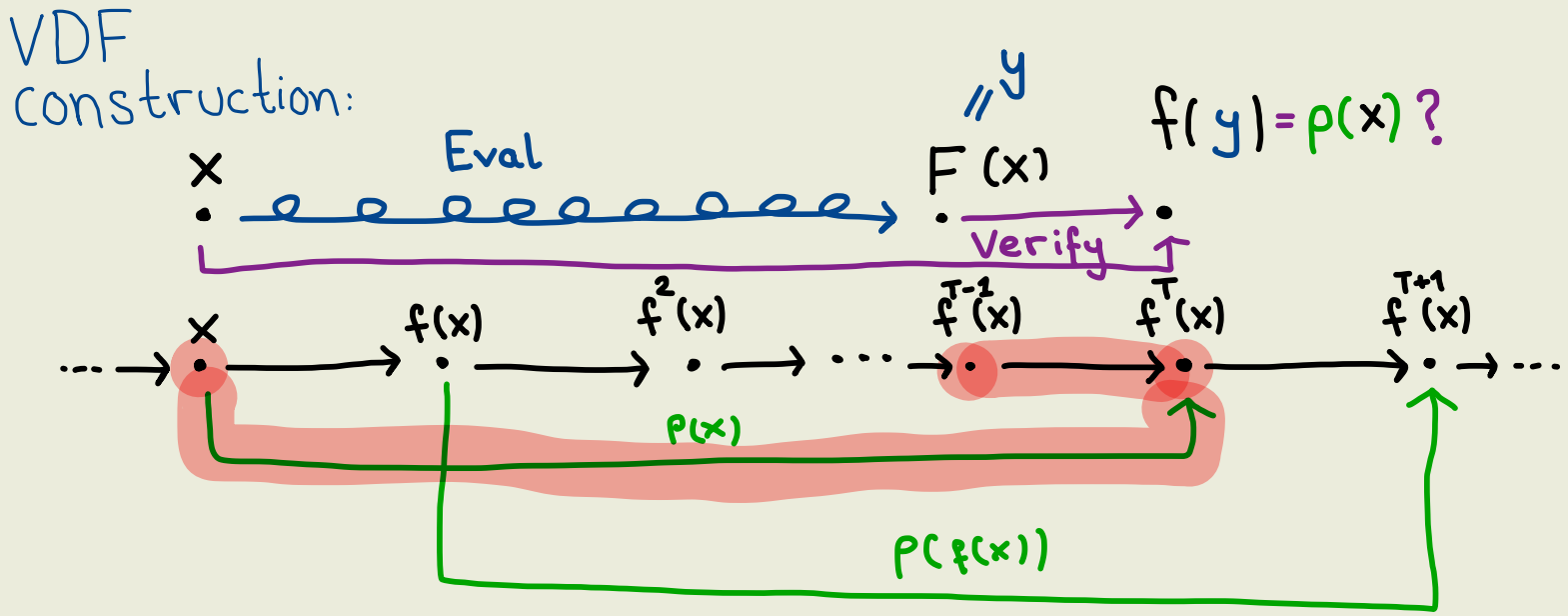

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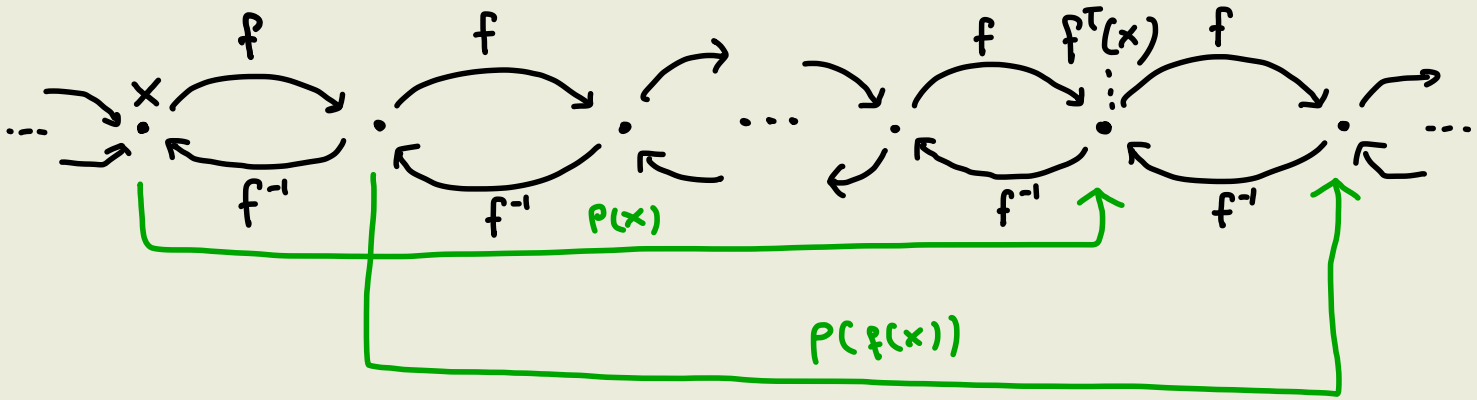

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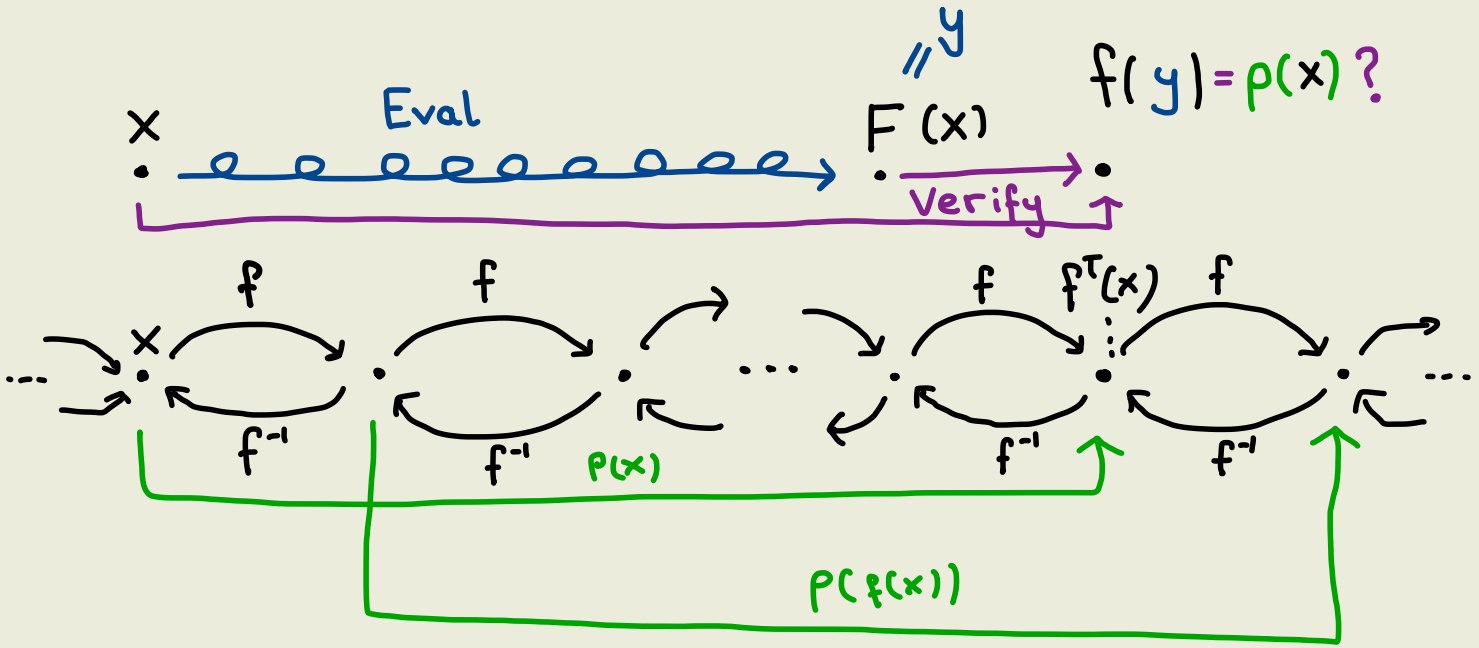

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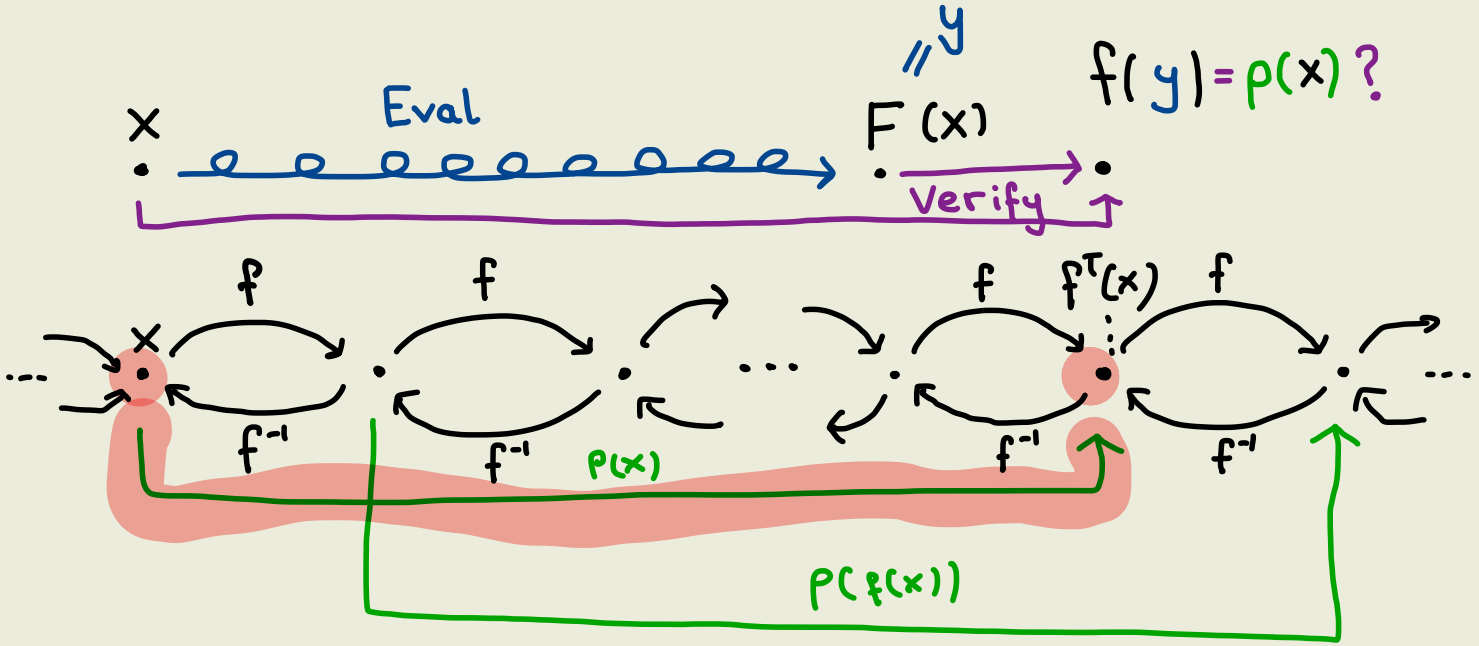

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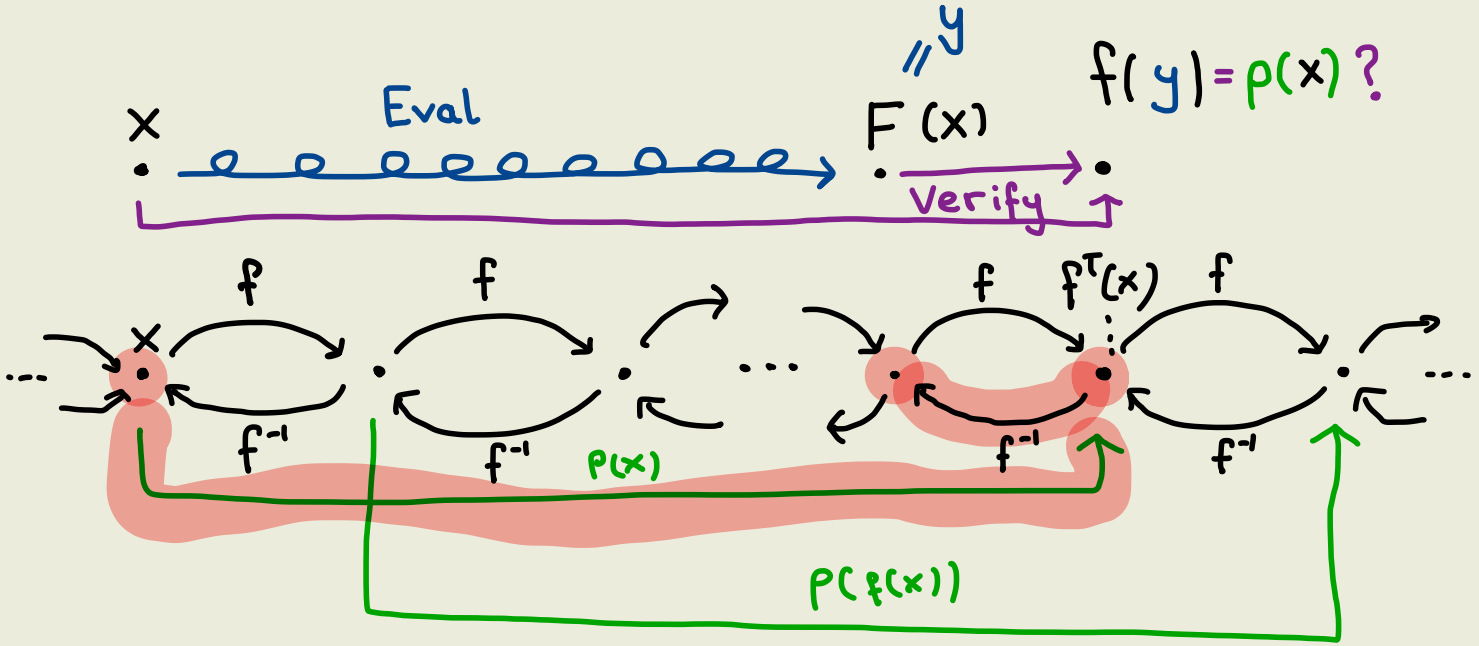

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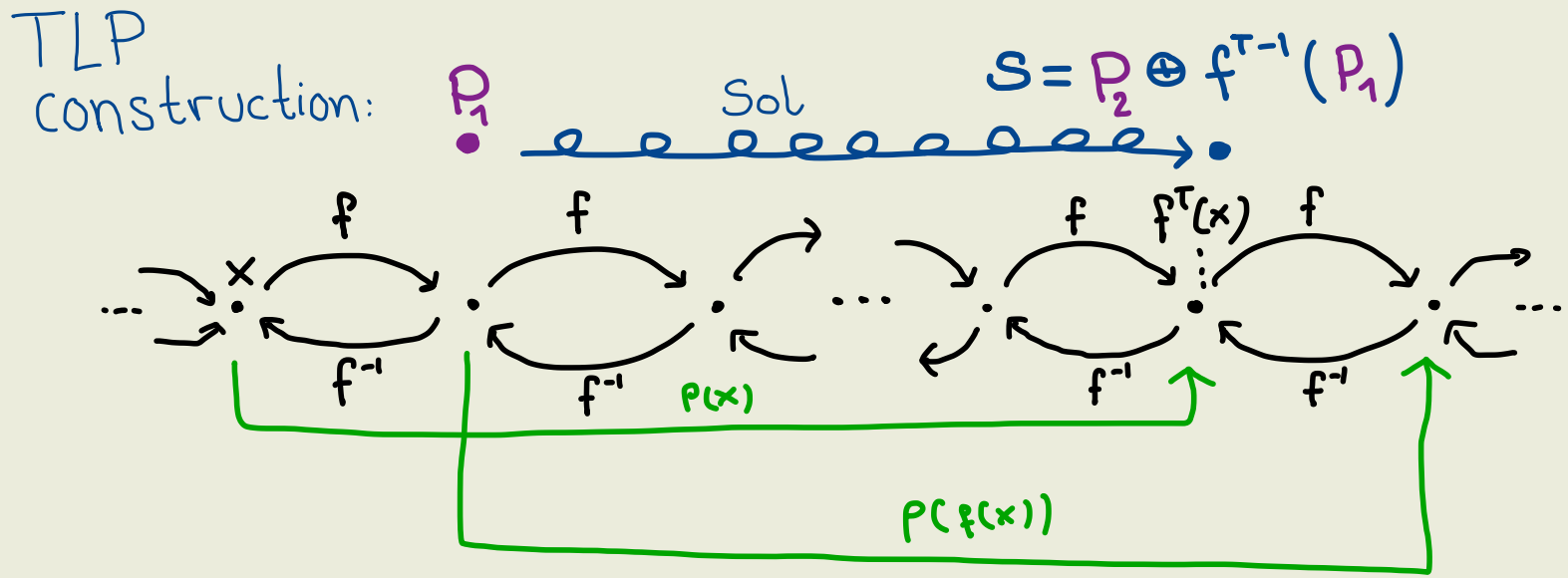

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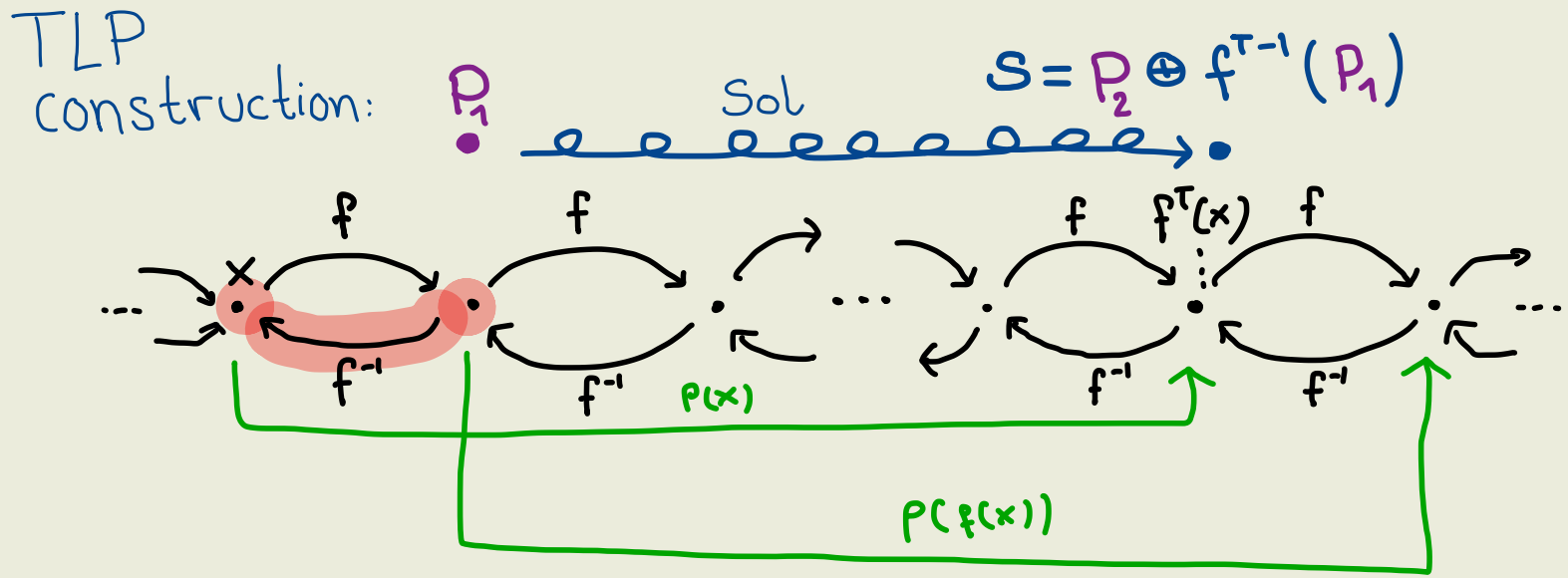

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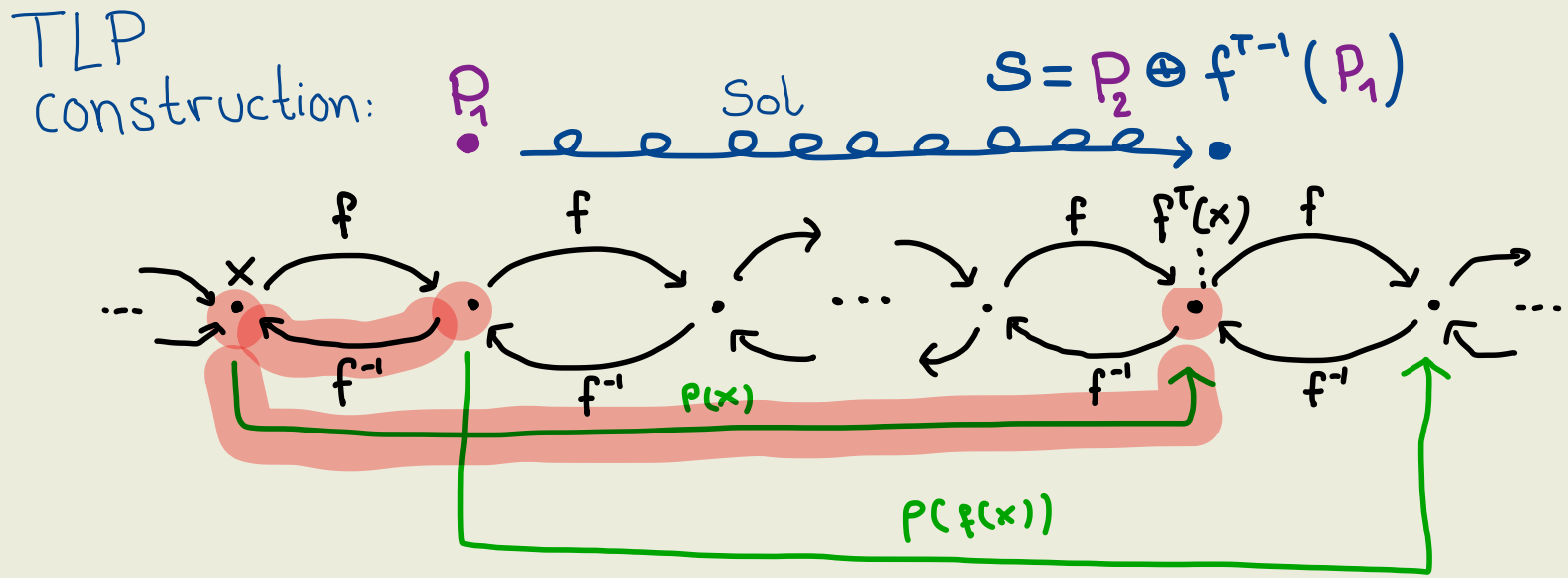

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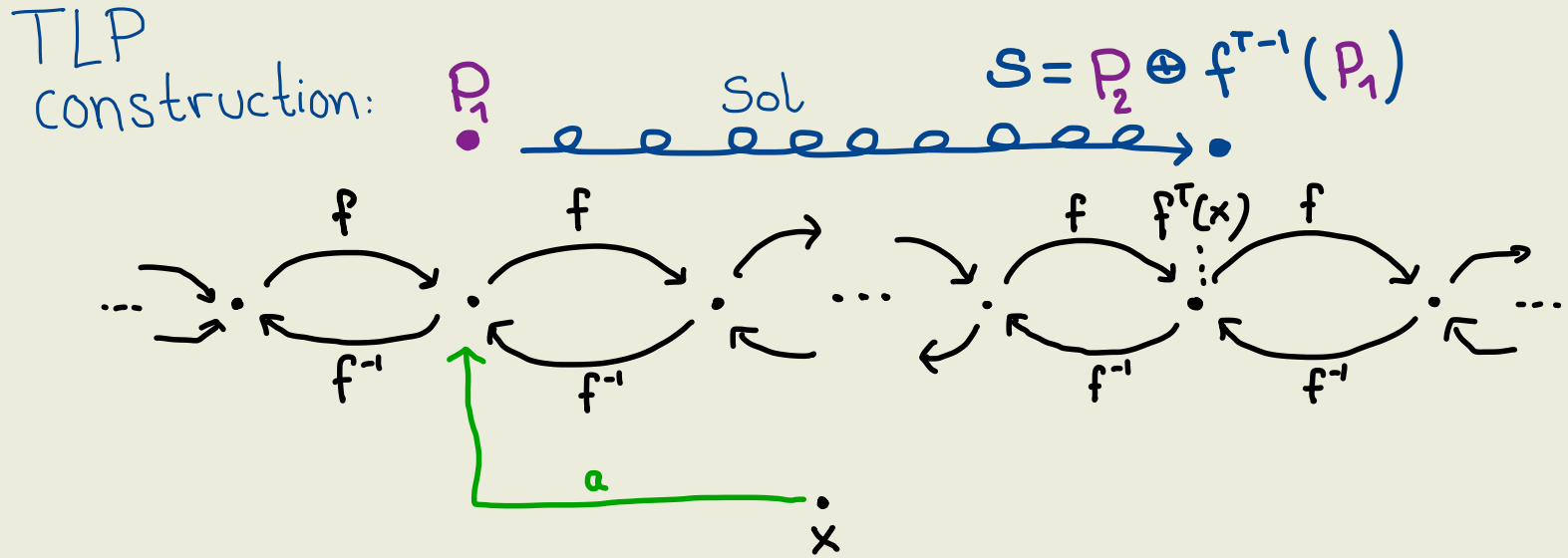

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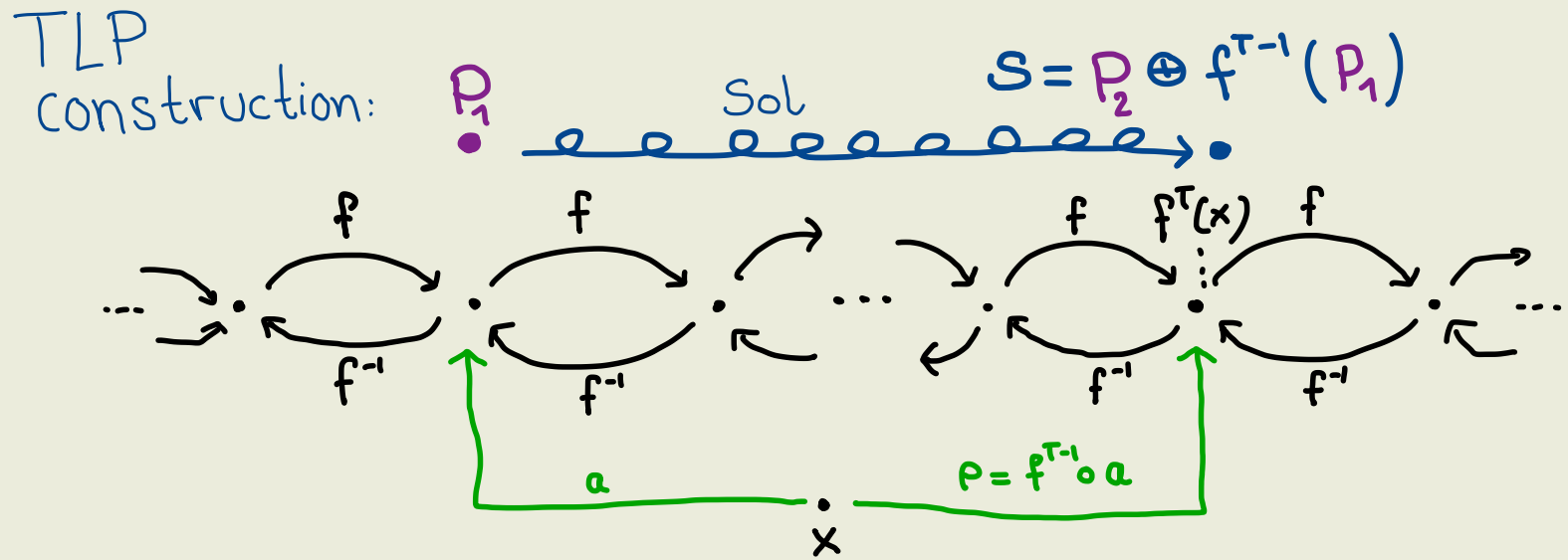

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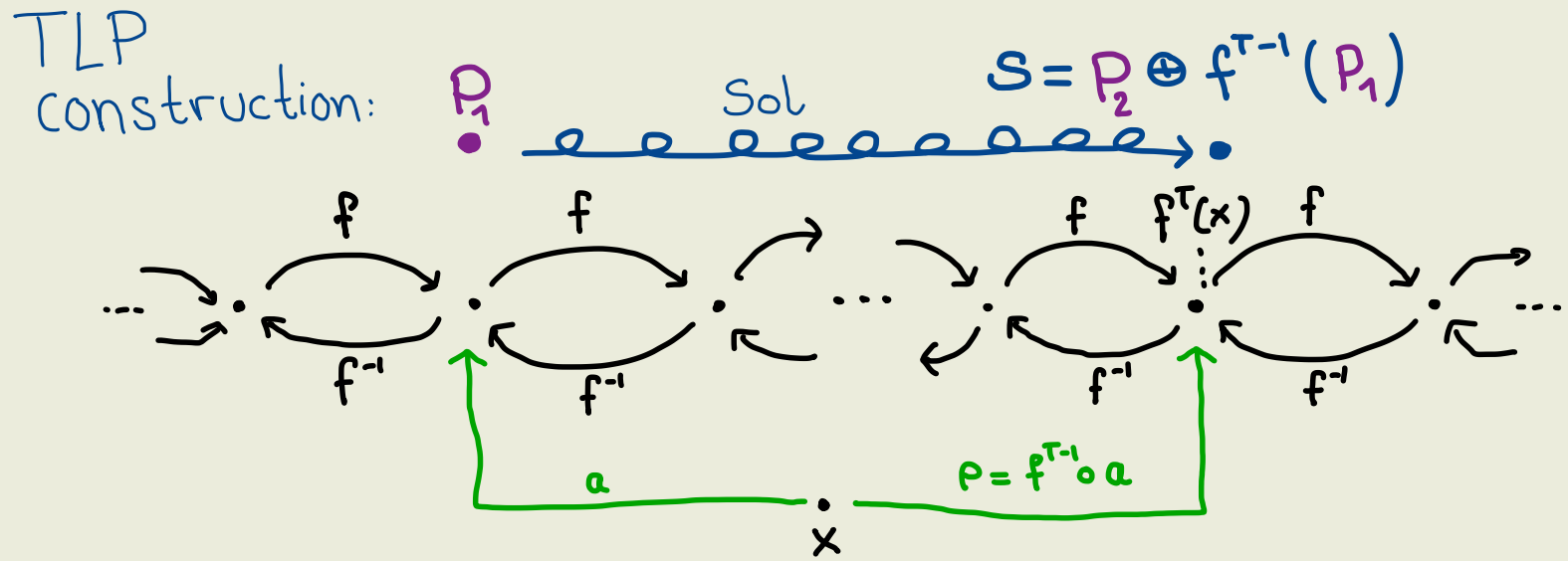

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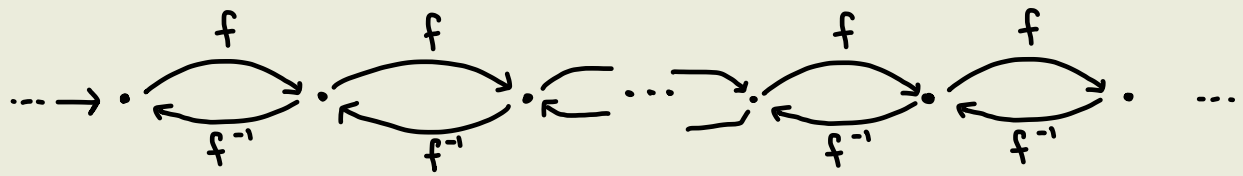

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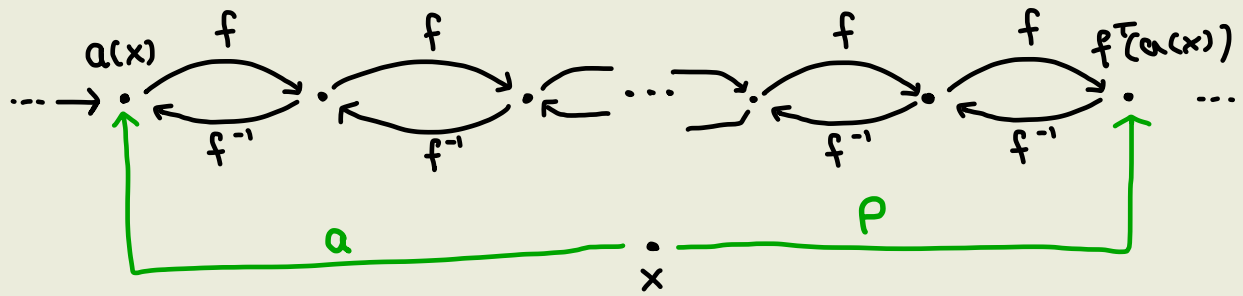

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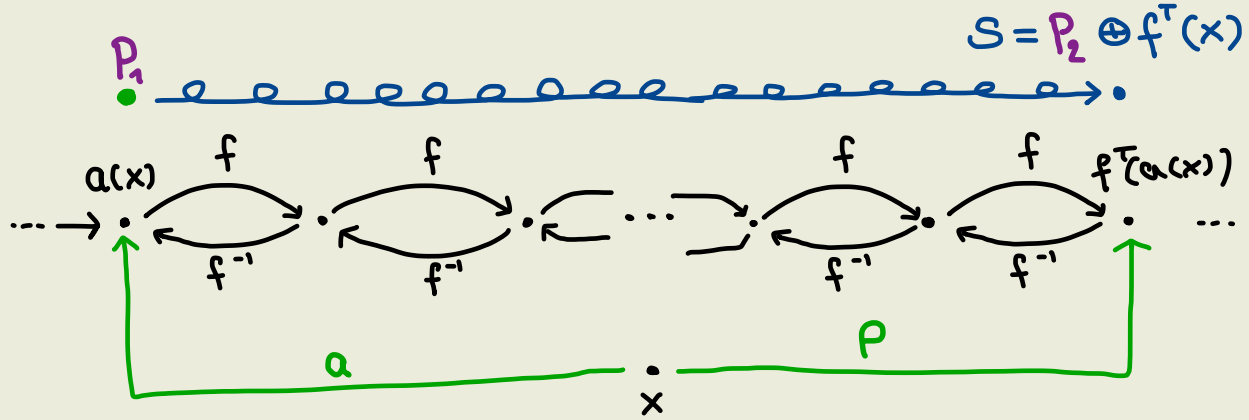

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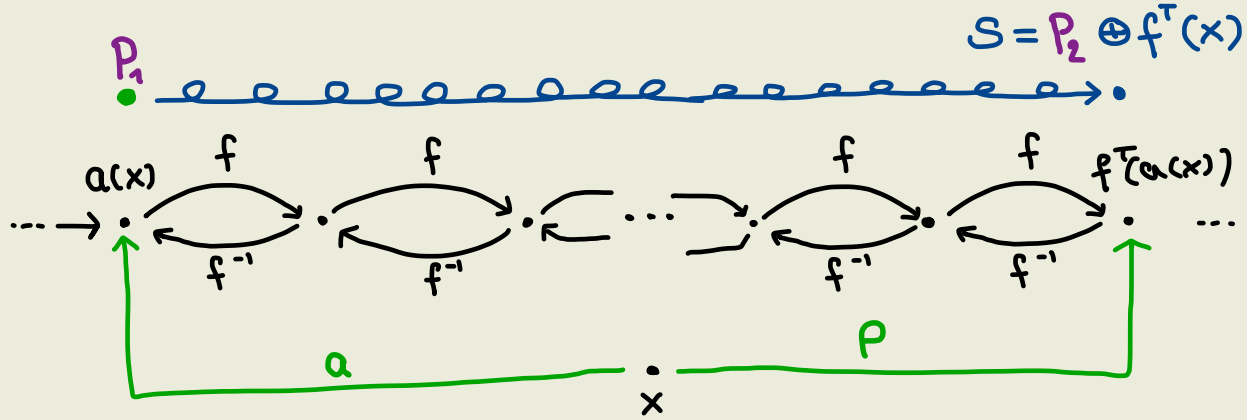

Now:

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- VDFs don't exist: the proof of [AAKTC25] can be made work in $\mathcal{M}_{\mathrm{TLP}}$. (with lots of work)

Thank you!

Questions?

References I

- Abusalah, Hamza et al. *Impossibility of VDFs in the ROM: The Complete Picture*. Cryptology ePrint Archive, Report 2025/1773. URL: https://eprint.iacr.org/2025/1773.
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