Robust Hyperproperty Preservation for Secure Compilation

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1 MAX PLANCK INSTITUTE FOR SOFTWARE SYSTEMS

2 Inria inventeurs du monde numérique

3 CISPA Center for IT-Security, Privacy and Accountability

Special Thanks to:




Contents

Background & Motivation

- many criteria imply secure compilation

  preserving memory safety, CFI, non interference, program equivalence

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Is that all?

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Goal: study criteria that

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- are robust (hold for all adversarial context)

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  preserving memory safety, CFI, non interference, program equivalence

Relate backtranslation techniques and property preservation

Goal:

- are security-driven and preserve security properties formally
- are robust (hold for all adversarial context)

HyperProperties Clarkson & Schneider '08

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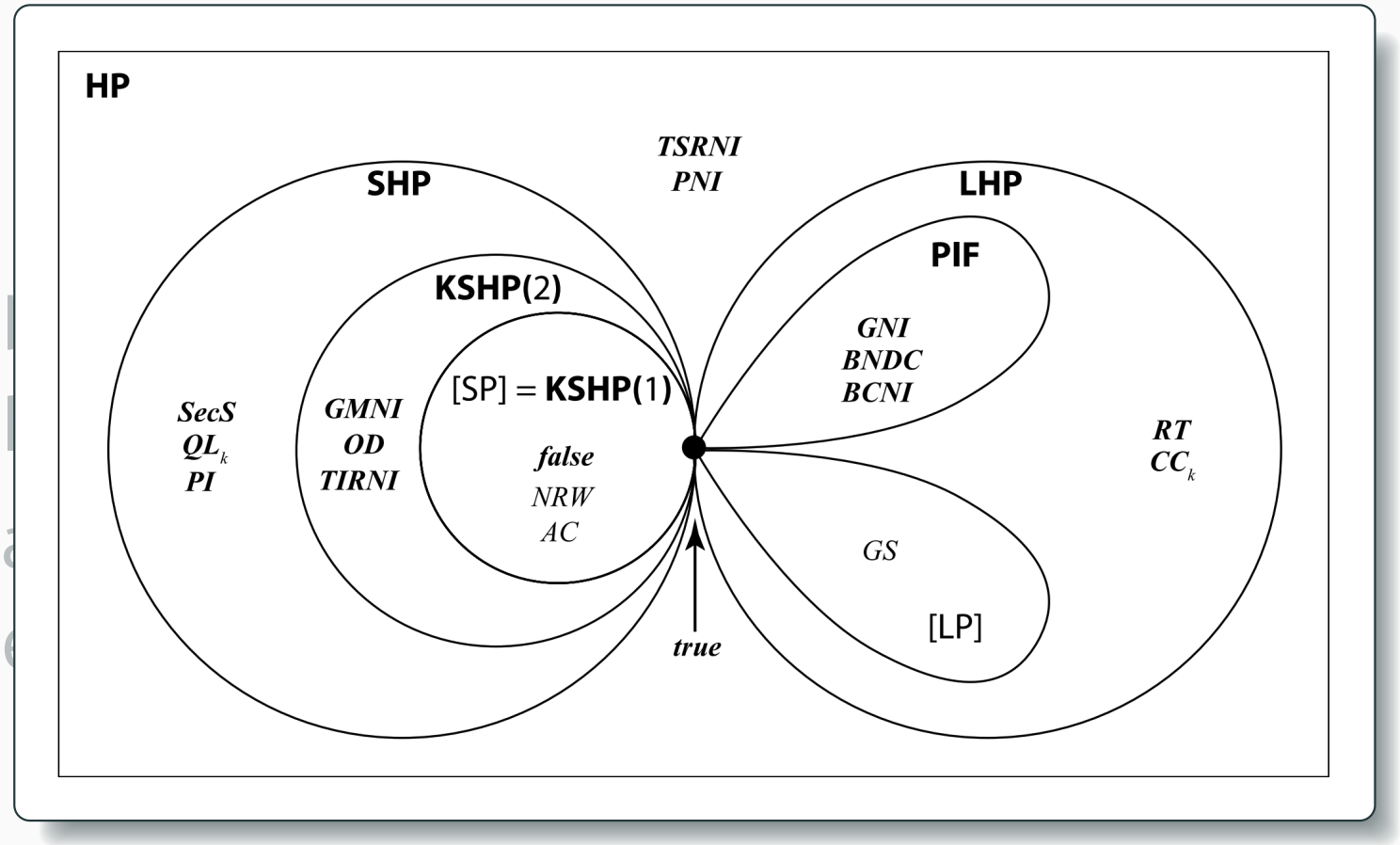
- hyperproperties = sets of sets of traces
- are organised in subclasses for expressiveness

HyperProperties Clarkson & Schneider '08



Robust Compilation Criteria

Robust Compilation Partial Order

In the partial order:

- higher notions are stronger

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- each notion comes in two flavours

Robust Compilation Partial Order

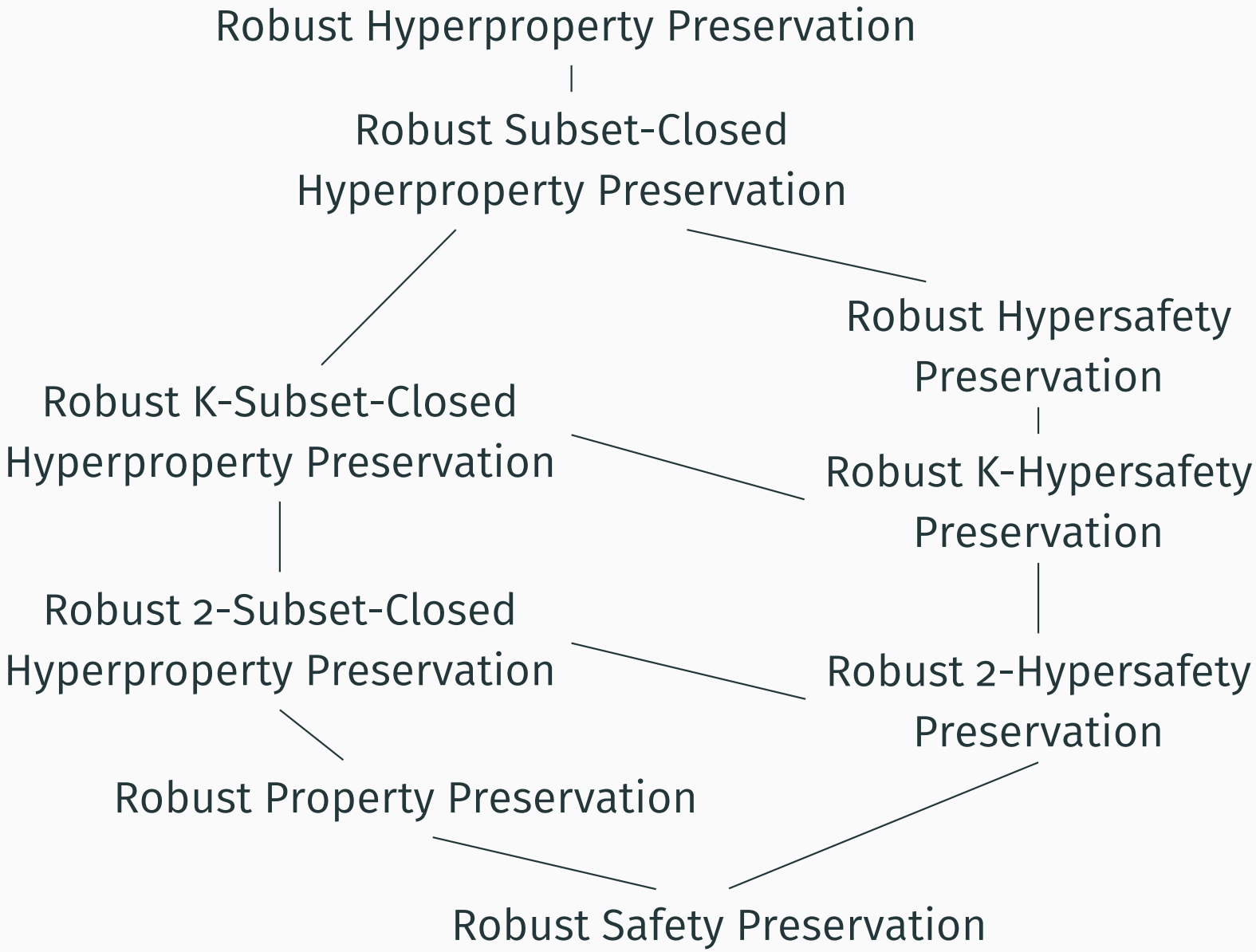
In the partial order:

- higher notions are stronger
  - and trickier to achieve
- each notion comes in two flavours
  - one with clear HP correspondence
  - one for simpler proofs

Notation

- $\mathrm{P_s}, \mathbf{P_t}$: components of S and $\mathbf{T}$
- $\mathbb{C}_\mathrm{s}\cdot, \mathbb{C}_\mathbf{t}\cdot$: contexts
- $\mathbb{C}_\mathrm{s}[\mathrm{P_s}], \mathbb{C}_\mathbf{t}[\mathbf{P_t}]$: whole programs
- $[\![\cdot]\!] : \mathrm{P_s} \to \mathbf{P_t}$: compiler from S to $\mathbf{T}$
- β: traces (possibly infinite), I/O with an environment
- $\mathtt{Behav}(\mathrm{P_s})$: set of traces of $\mathrm{P_s}$
- π: prefix (finite)
- $\prec$: prefixing

Robust Compilation Criteria



RPP: **Robust Property Preservation**

Definition (RPP)

$$[\![\cdot]\!] \in \mathrm{RPP} \stackrel{\mathrm{def}}{=} \forall \mathrm{P_s}, \mathtt{P}.$$
$$\text{if} \quad (\forall \mathbb{C}_s.\mathtt{Behav}\,(\mathbb{C}_s\,[\mathrm{P_s}]) \subseteq \mathtt{P})$$
$$\text{then} \quad (\forall \mathbb{C}_t.\mathtt{Behav}\,(\mathbb{C}_t\,[[\![\mathrm{P_s}]\!]]) \subseteq \mathtt{P})$$

RC: **Robust Compilation**

Definition: (RC)

$$[\![\cdot]\!] \in \mathrm{RC} \stackrel{\text{def}}{=} \forall \mathbb{C}_t, \mathrm{P}_s, \beta. \exists \mathbb{C}_s.$$
$$\text{if} \quad \beta \in \mathtt{Behav}\left(\mathbb{C}_t\left[[\![\mathrm{P}_s]\!]\right]\right)$$
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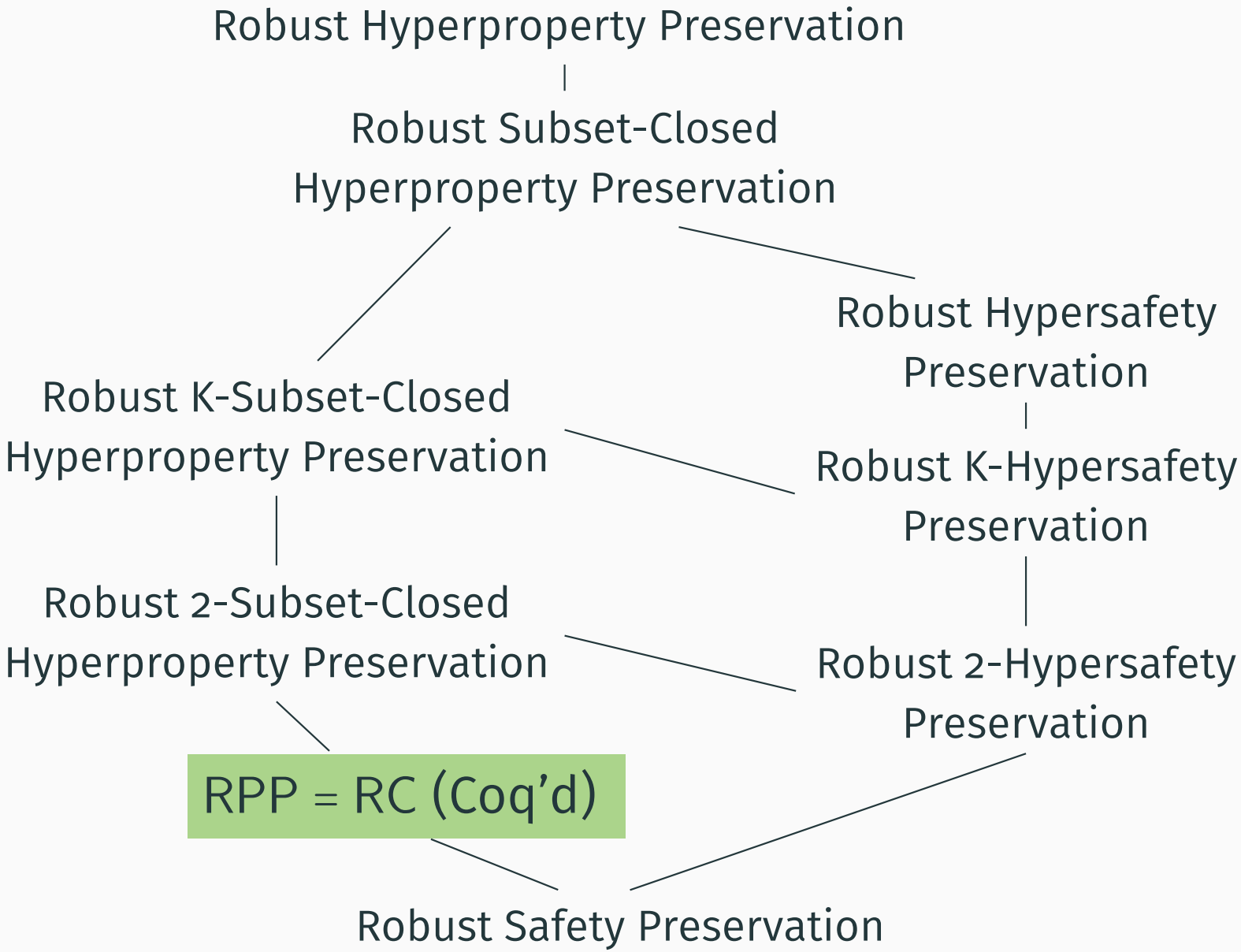

Robust Safety Property Preservation

Definition (RSPP)

$$[\![\cdot]\!] \in \mathrm{RSPP} \stackrel{\mathrm{def}}{=} \forall \mathrm{P_s}, \mathrm{P} \in SP\ .$$
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Robust Safety Compilation

Definition: (SRC)

$$[\![\cdot]\!] \in \mathrm{SRC} \stackrel{\text{def}}{=} \forall \mathbb{C}_t, \mathrm{P}_s, \pi . \exists \mathbb{C}_s .$$
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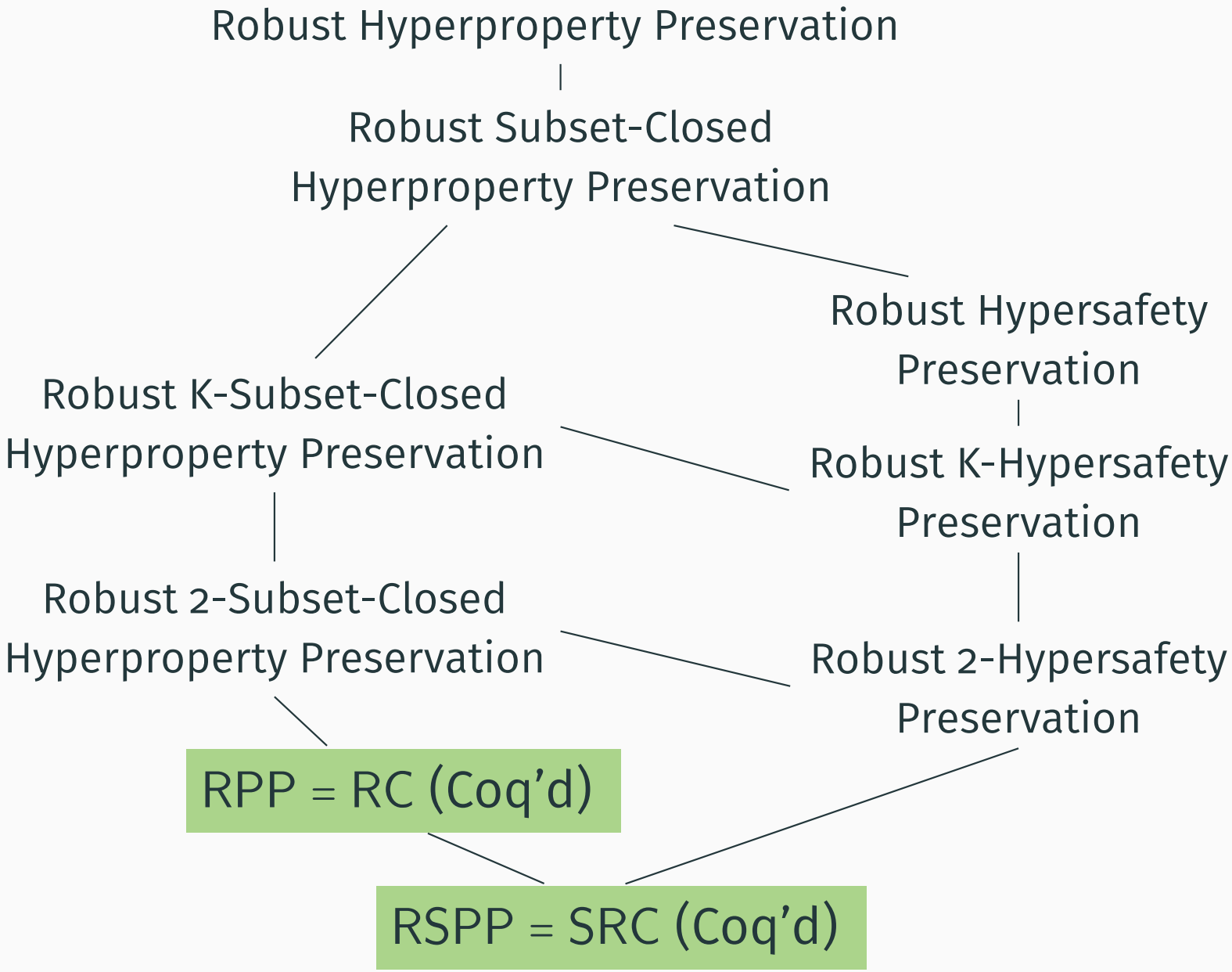
Robust Compilation Criteria



RSHP: **Robust Hypersafery Preservation**

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$$[\![\cdot]\!] \in \text{RSHP} \stackrel{\text{def}}{=} \forall \mathtt{P_s}, \mathtt{H} \in \mathit{SHP}.$$
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SHRC: **Hypersafety Robust Compilation**

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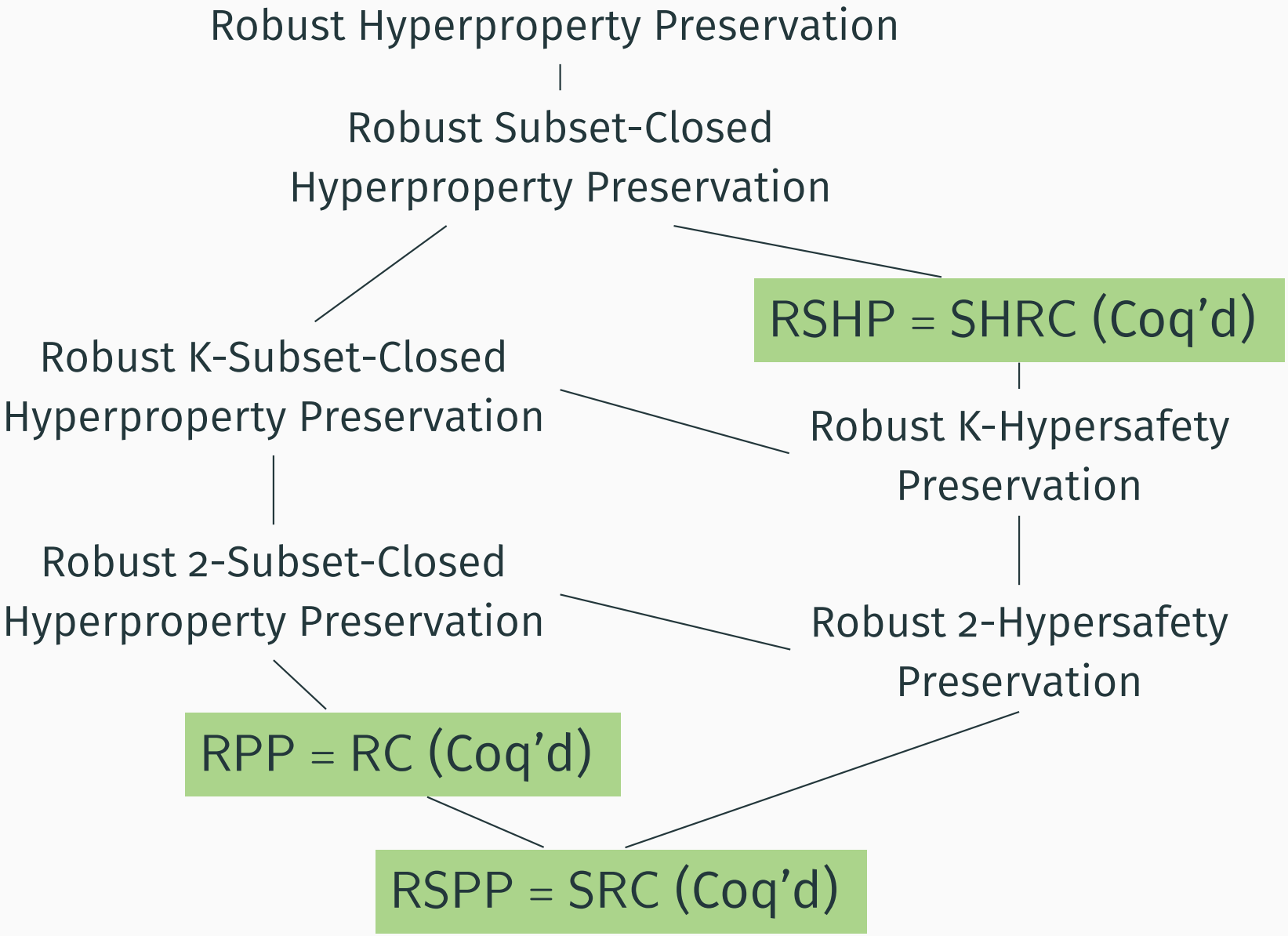
$$[\![\cdot]\!] \in \mathsf{SHRC} \stackrel{\text{def}}{=} \forall \mathtt{P_s}, \mathbb{C}_\mathtt{t}, \hat{\pi}.\exists \mathbb{C}_\mathtt{s}.$$
$$\text{if } \hat{\pi} \precsim \mathtt{Behav}\,(\mathbb{C}_\mathtt{t}\,[[\mathtt{P_s}]])$$
$$\text{then } \hat{\pi} \precsim \mathtt{Behav}\,(\mathbb{C}_\mathtt{s}\,[\mathtt{P_s}])$$

$\hat{\pi}$: finite set of prefixes

Robust Compilation Criteria



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Hyperproperty Robust Compilation

Definition: (HRC)

$$[\![\cdot]\!] \in \mathsf{HRC} \stackrel{\text{def}}{=} \forall \mathbb{C}_t, \mathrm{P}_s, \exists \mathbb{C}_s. \forall \beta.$$
$$\beta \in \mathtt{Behav}\left(\mathbb{C}_t\left[[\![\mathrm{P}_s]\!]\right]\right)$$
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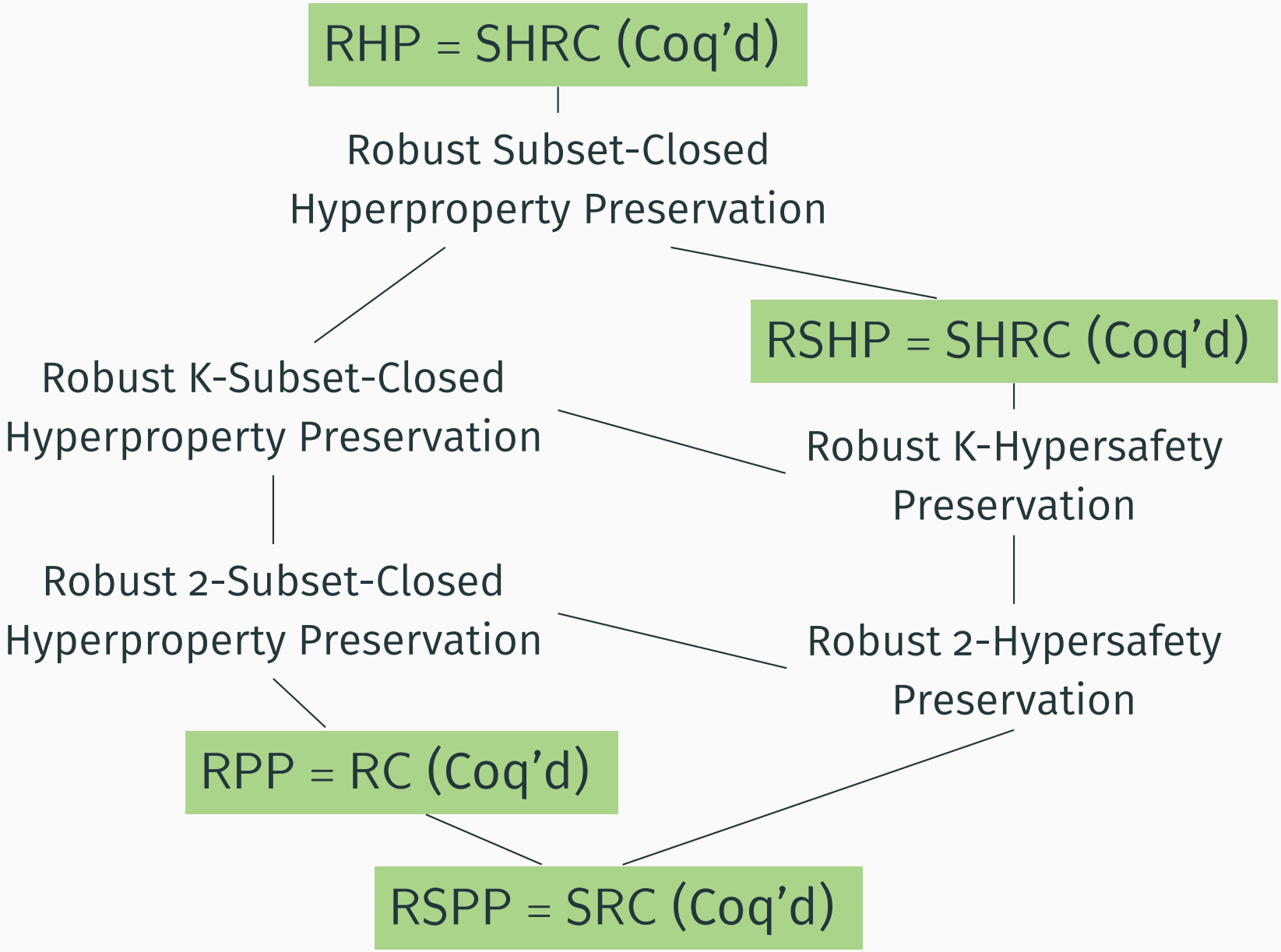

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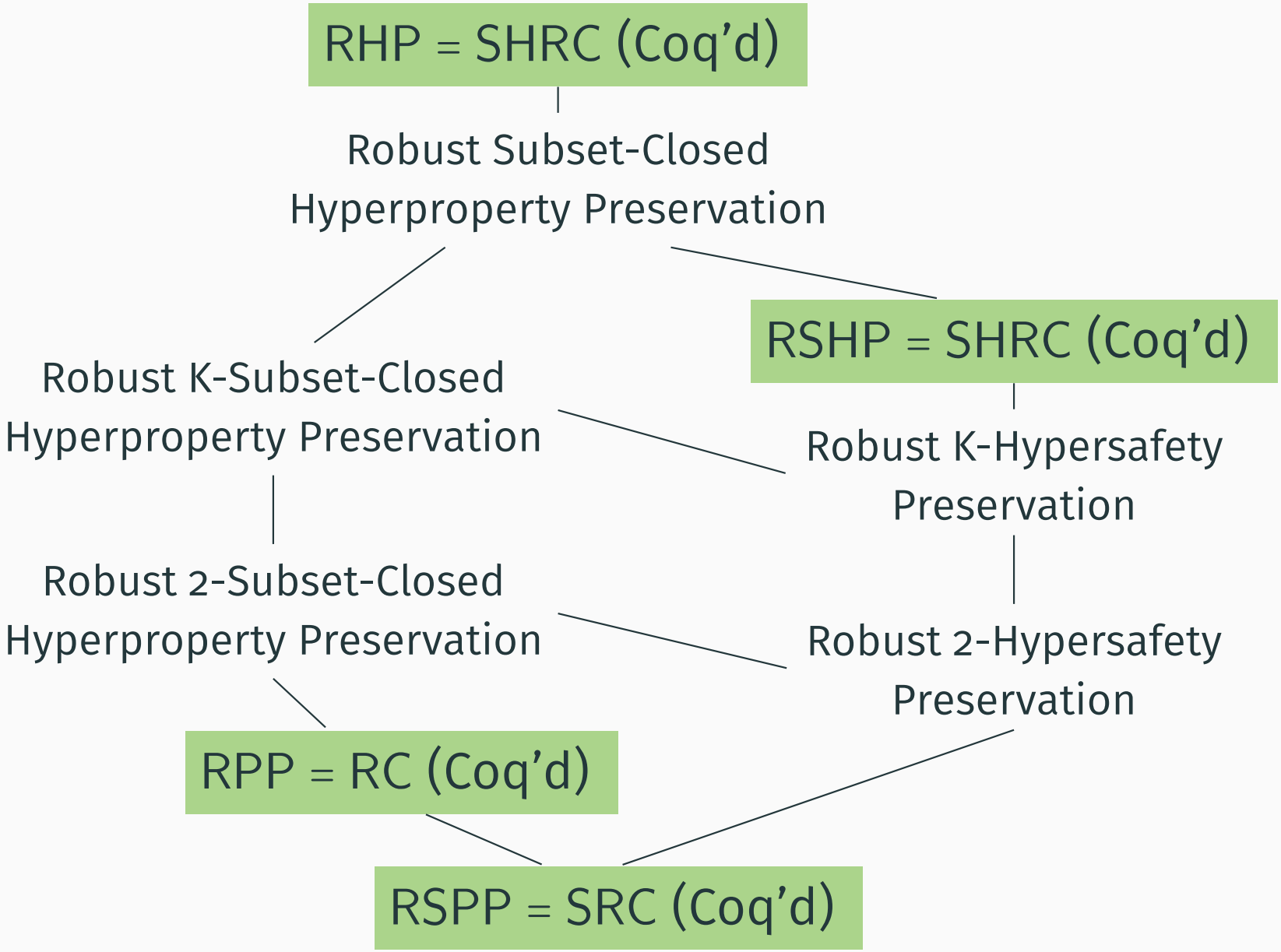

Proof Techniques

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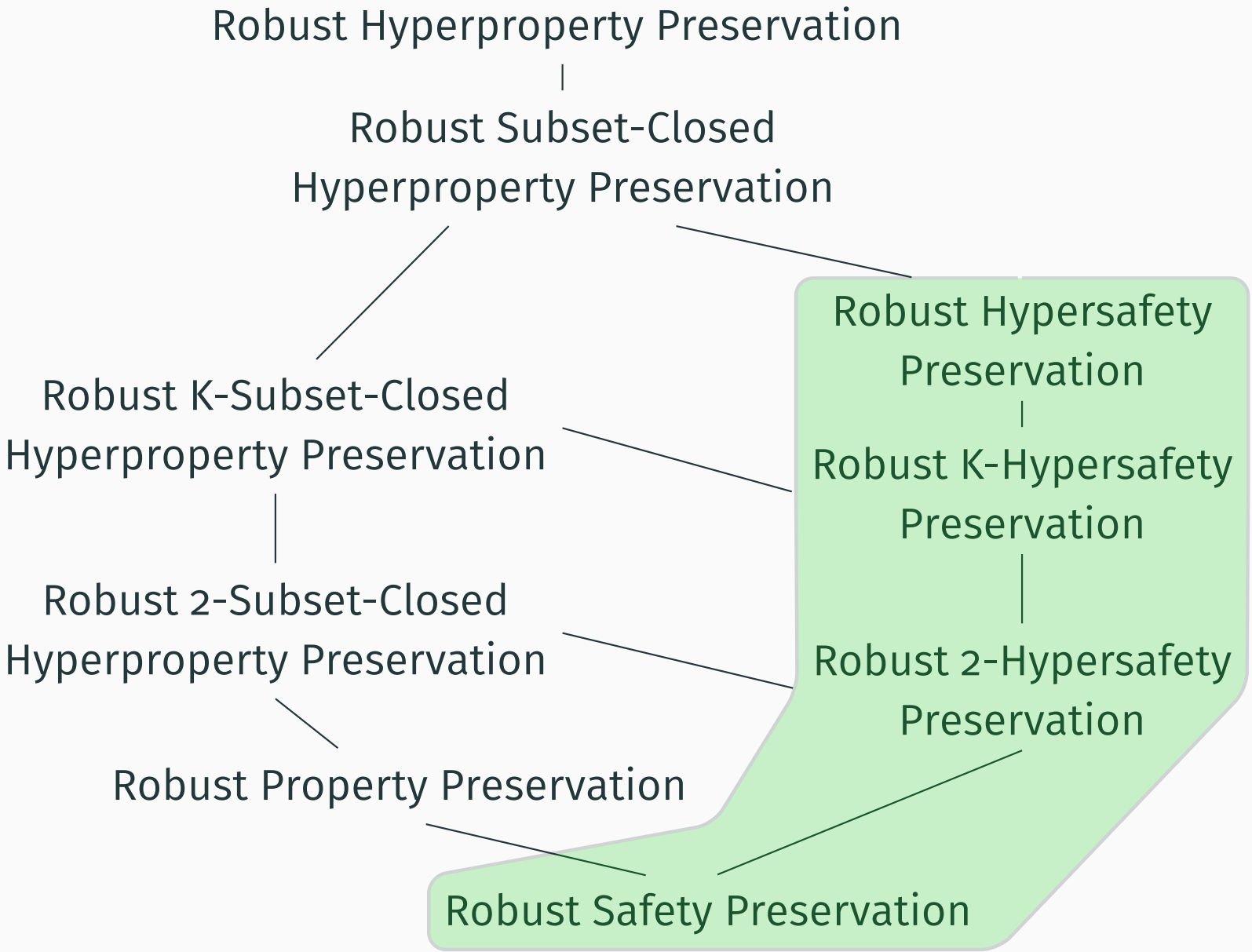

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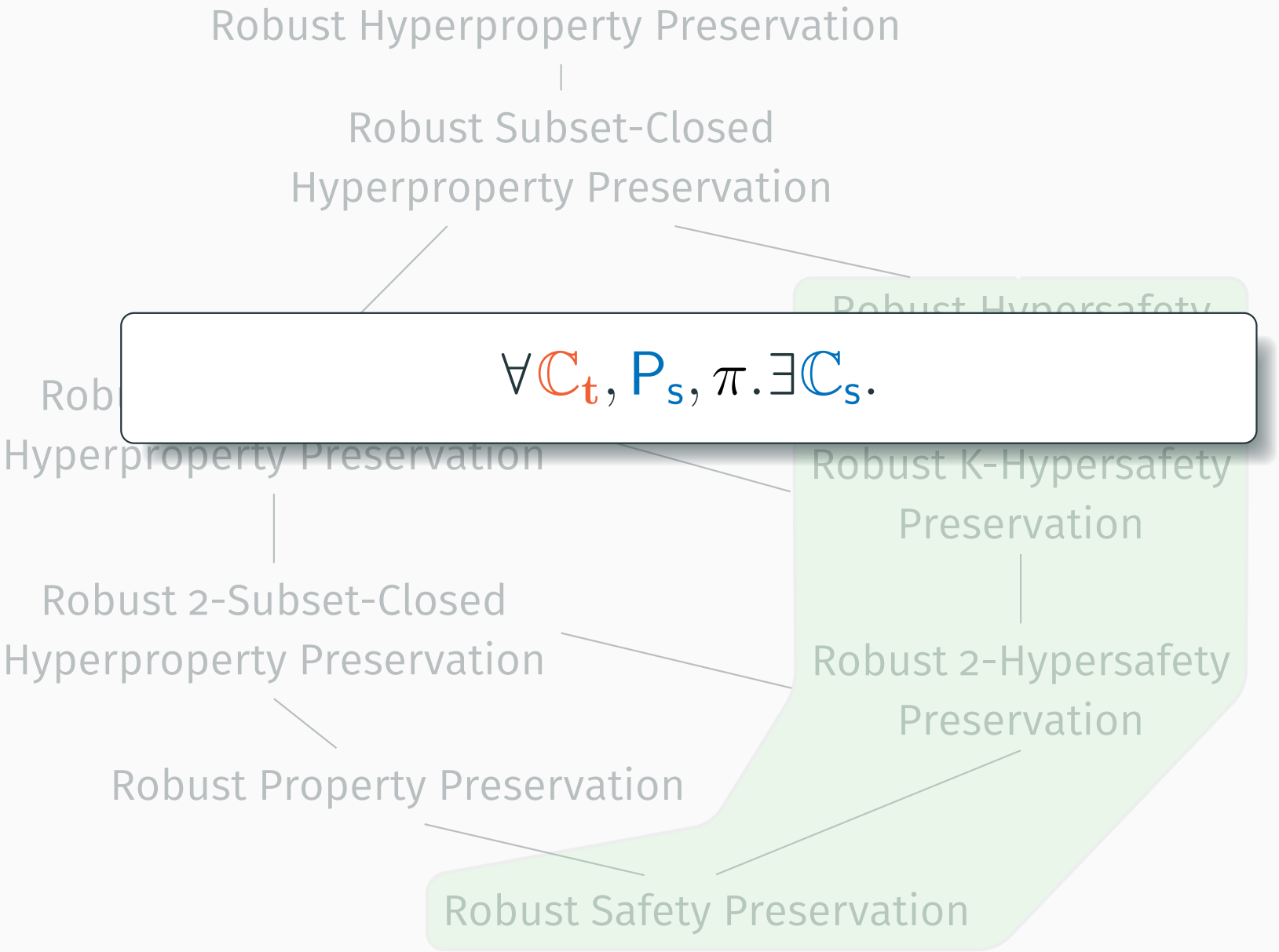

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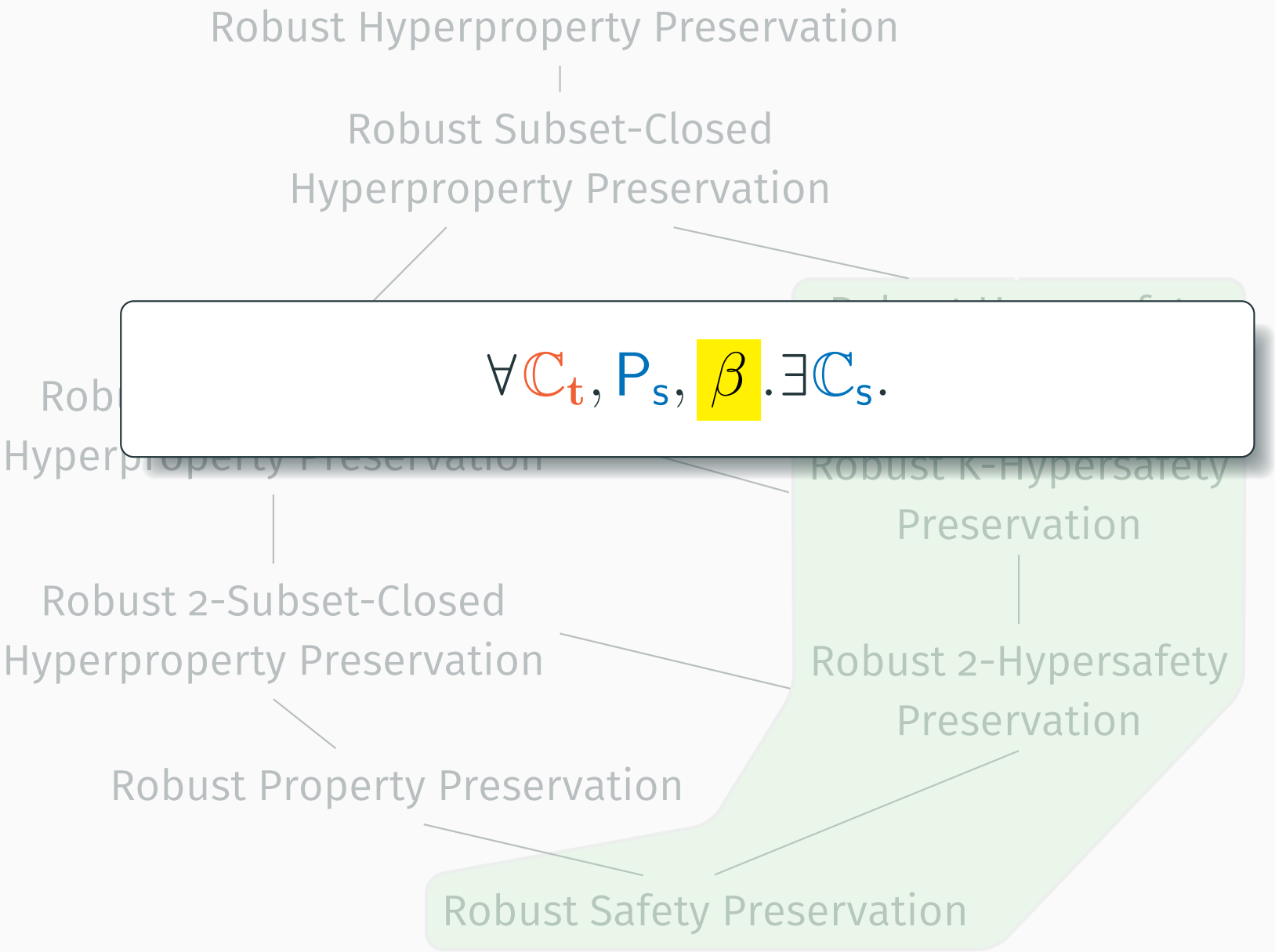
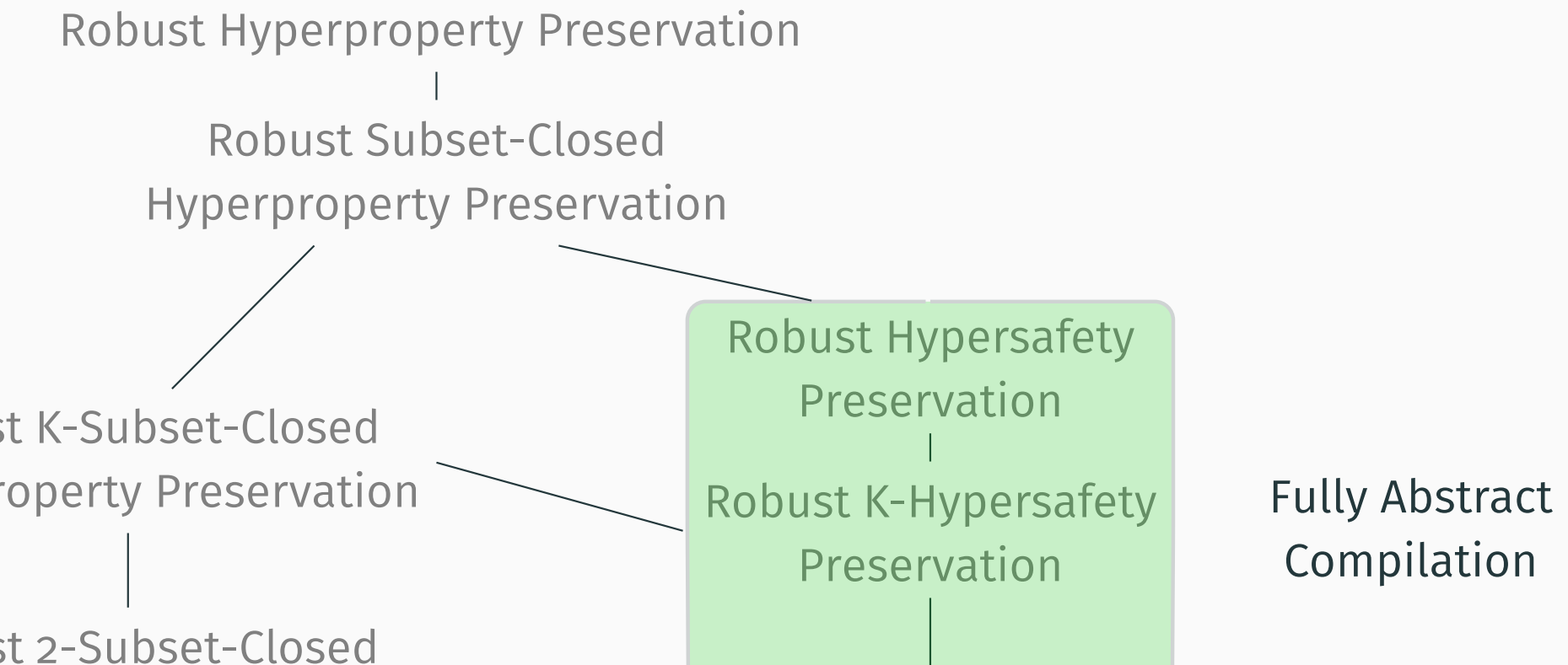


Where is FAC?

There is FAC



Fully Abstract
Compilation

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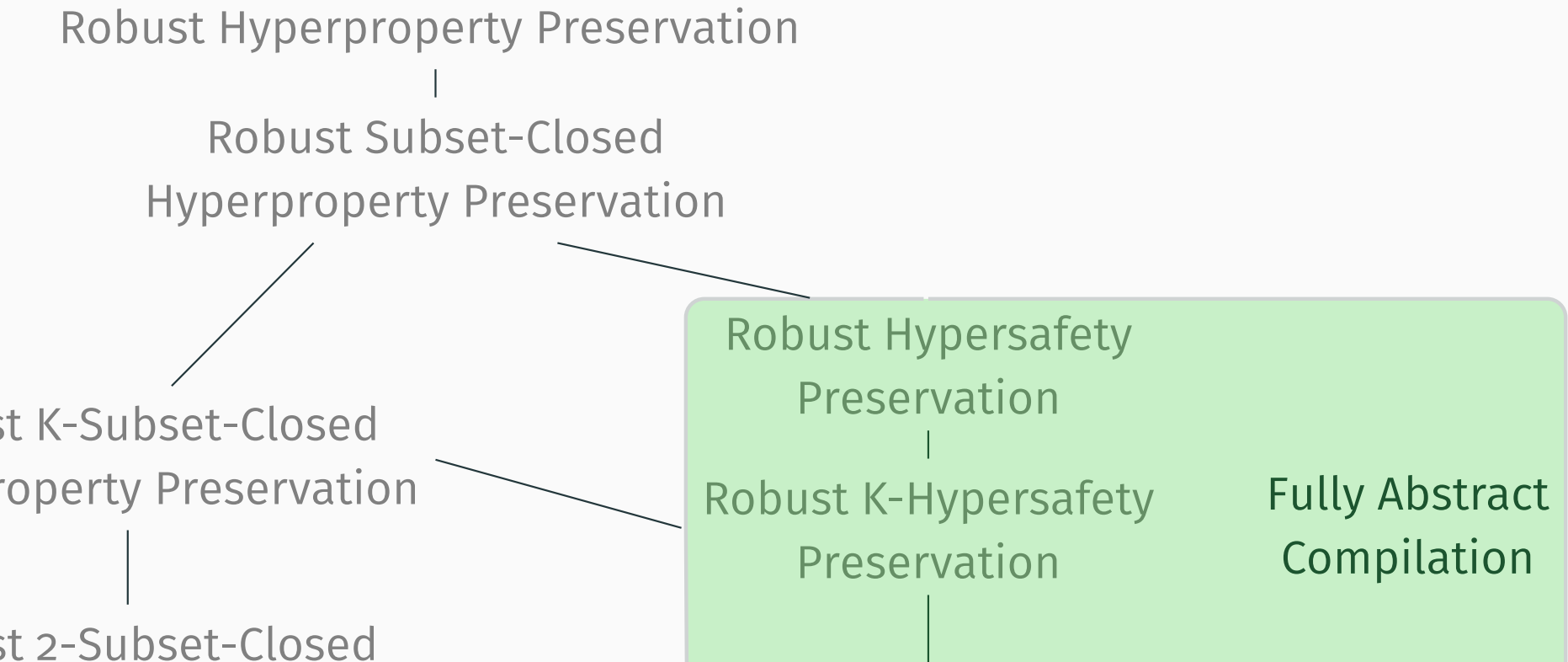
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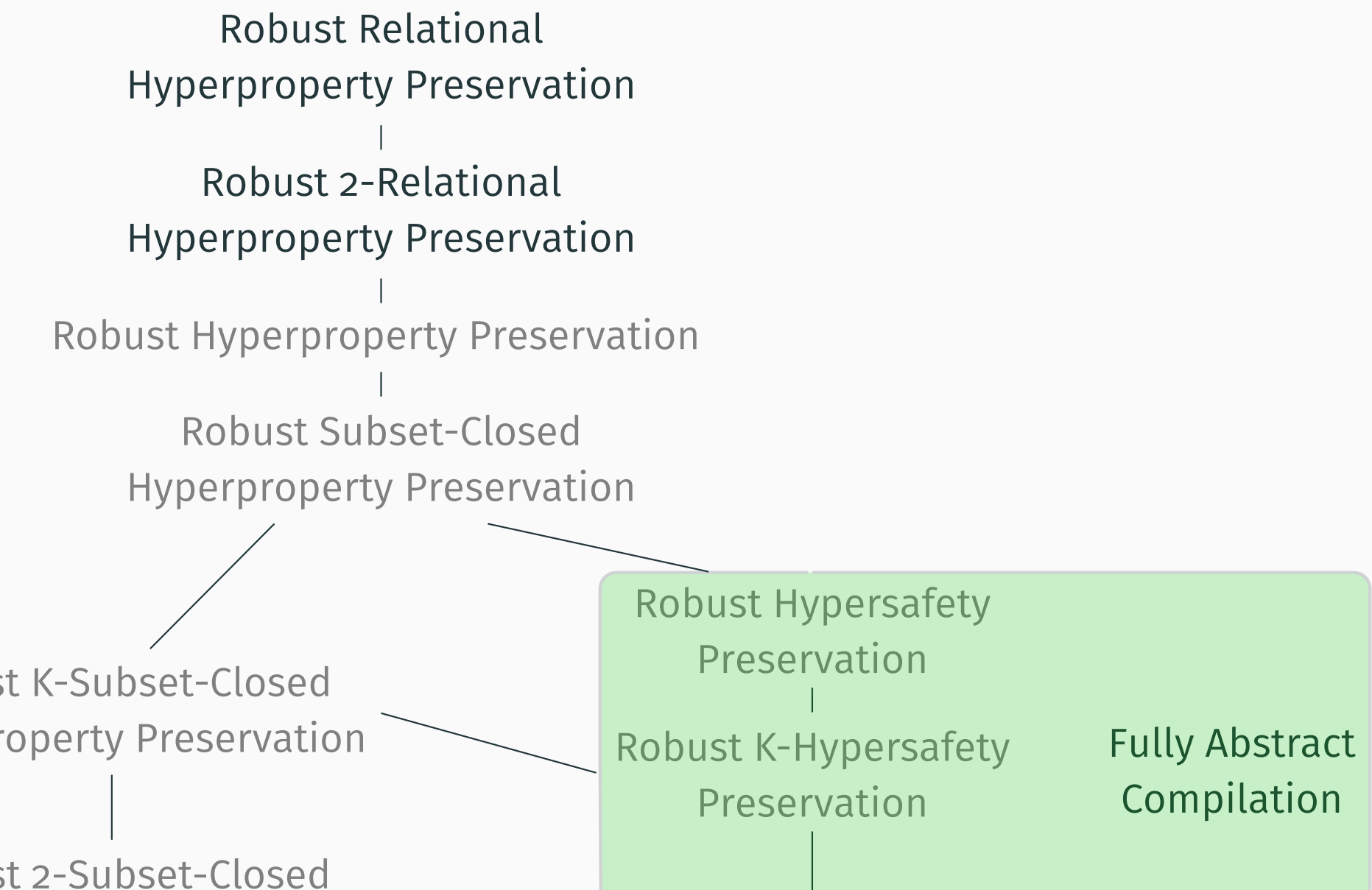
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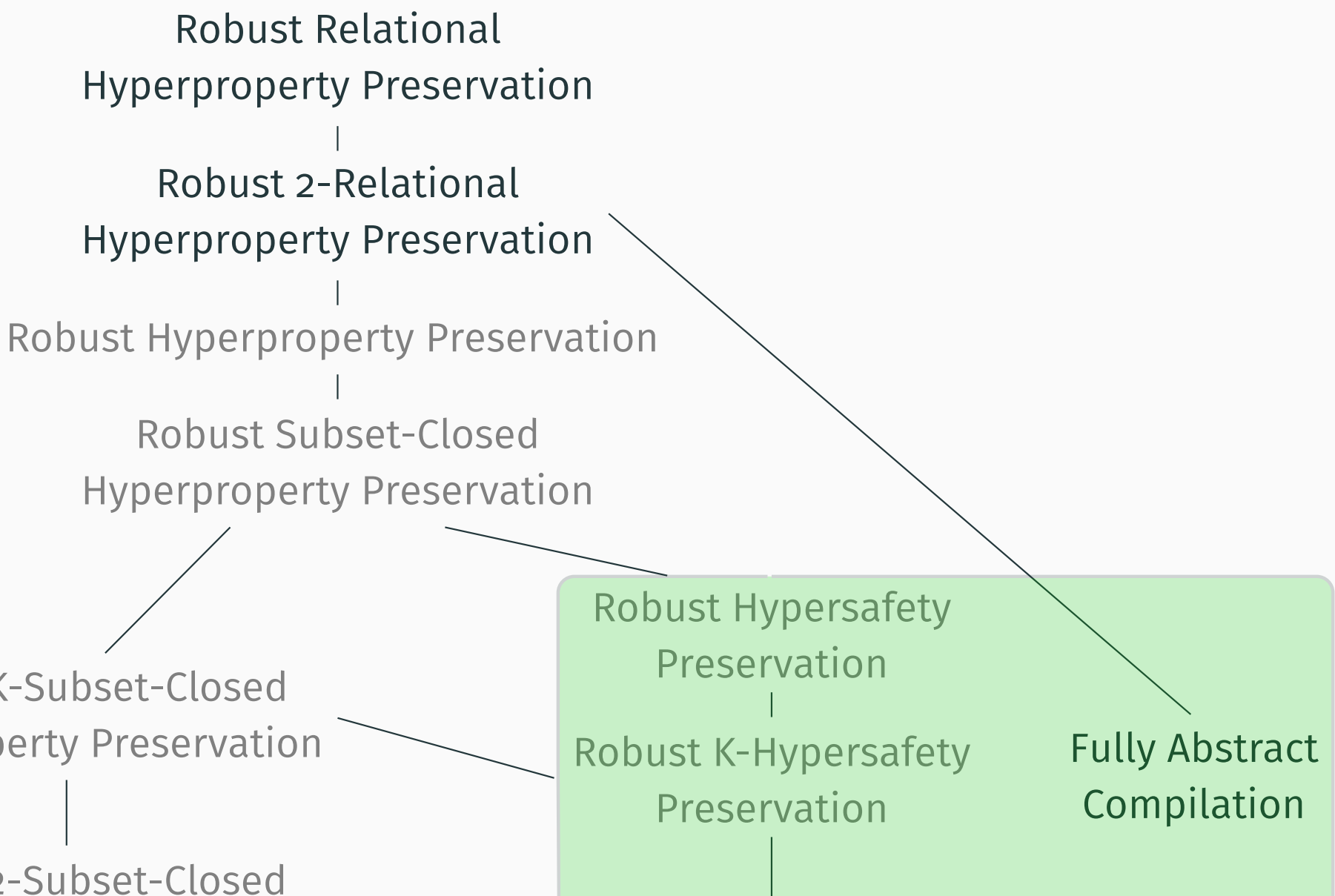
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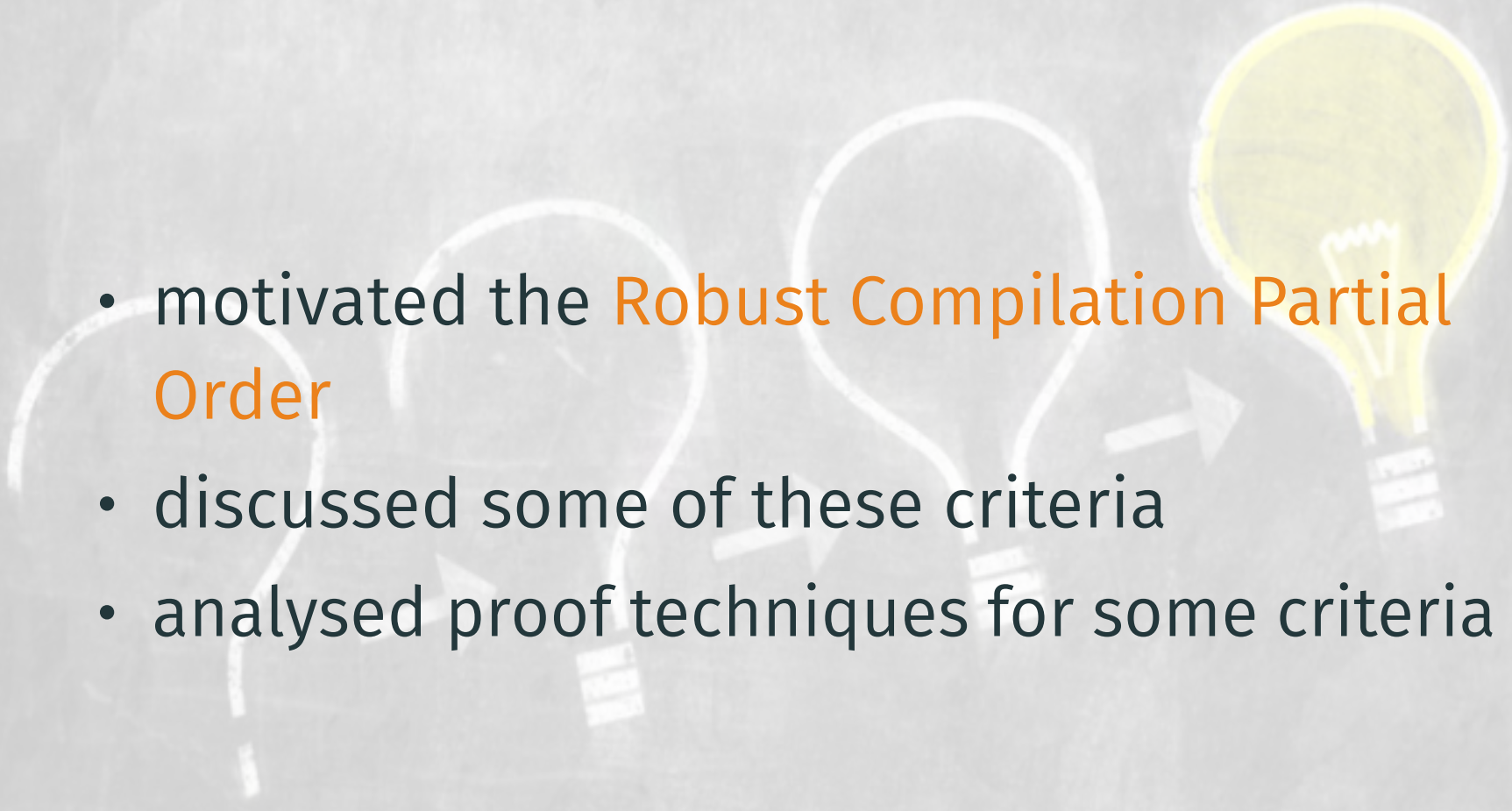

- motivated the Robust Compilation Partial Order
- discussed some of these criteria
- analysed proof techniques for some criteria

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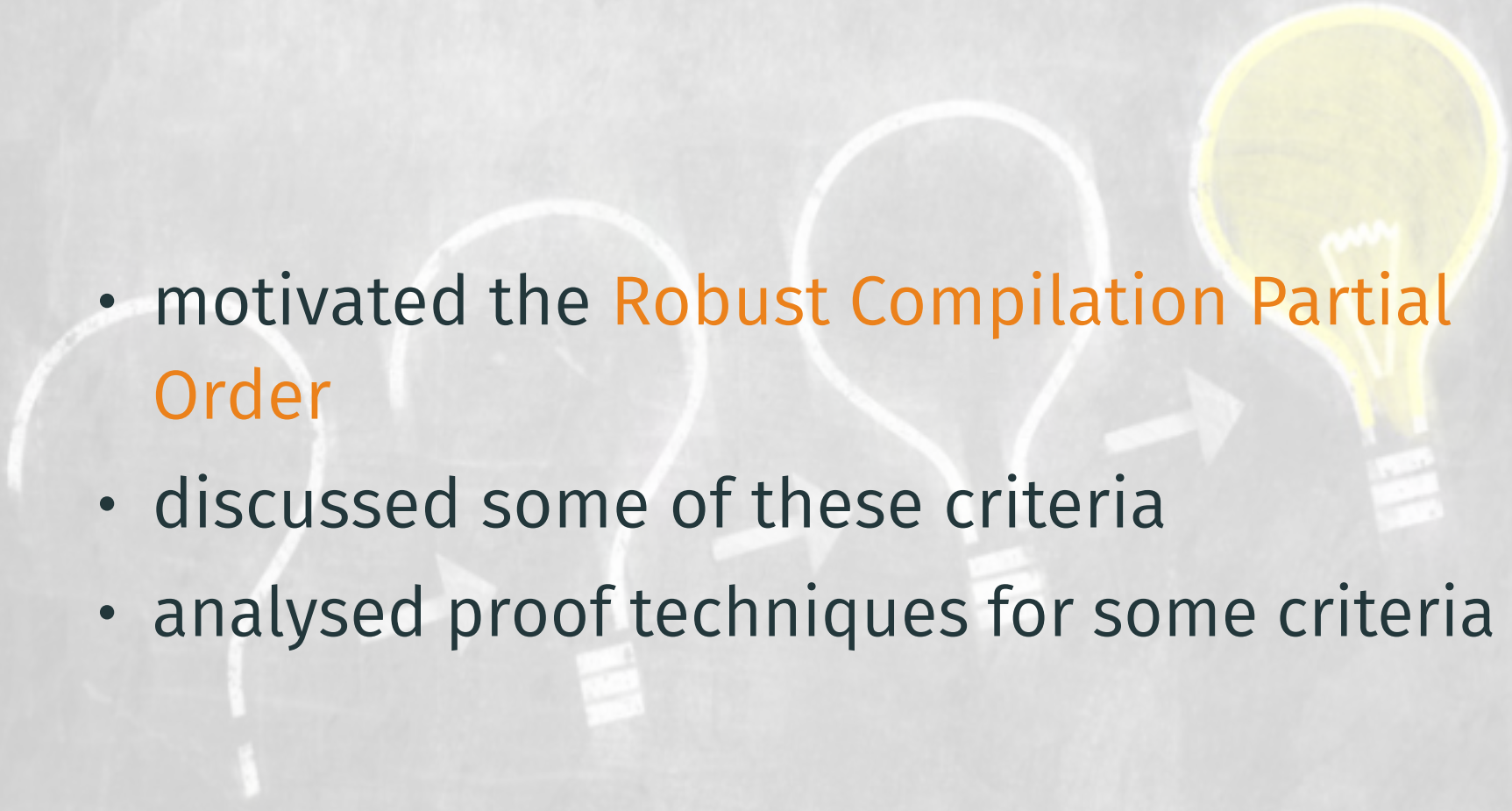

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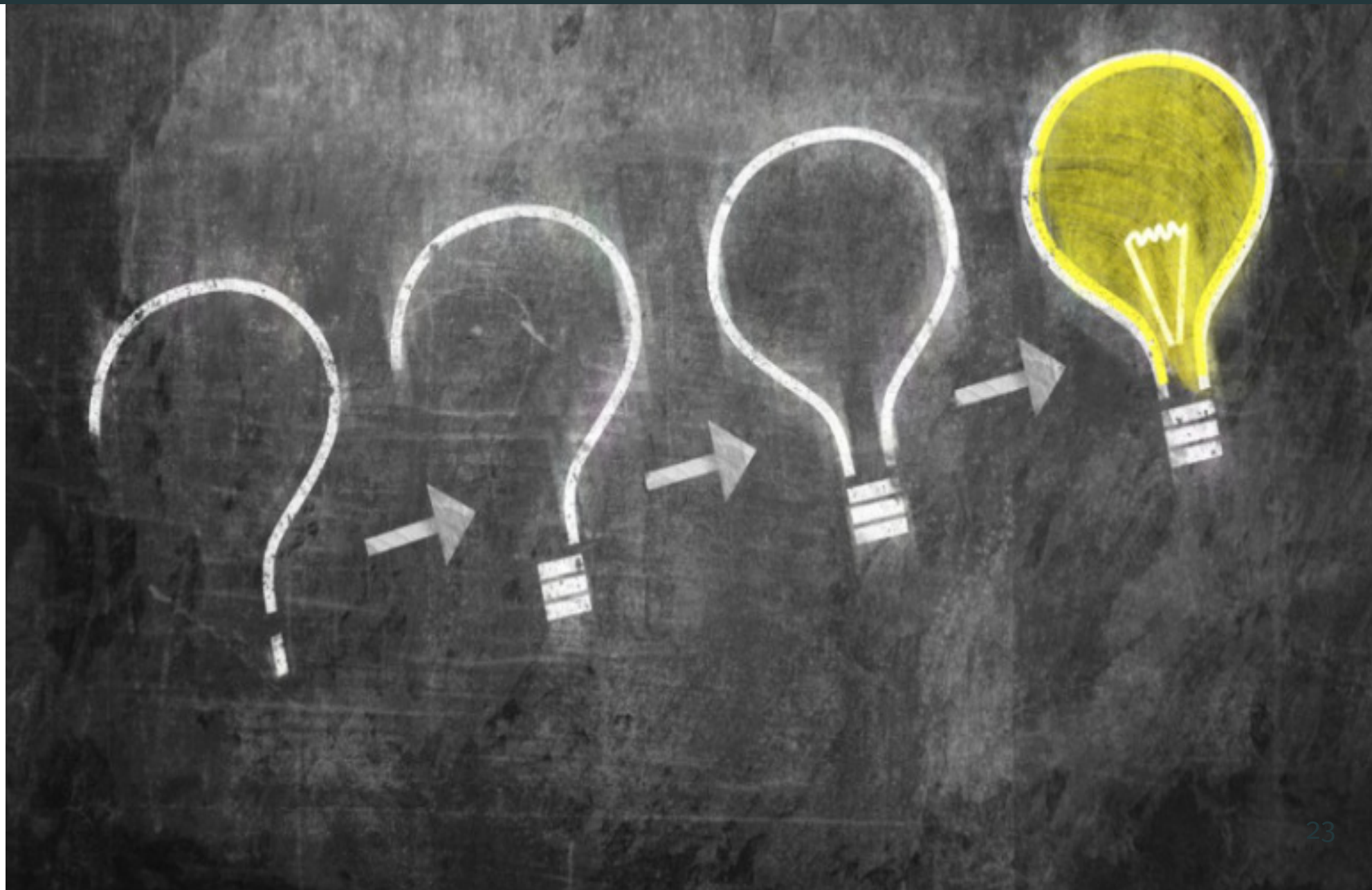

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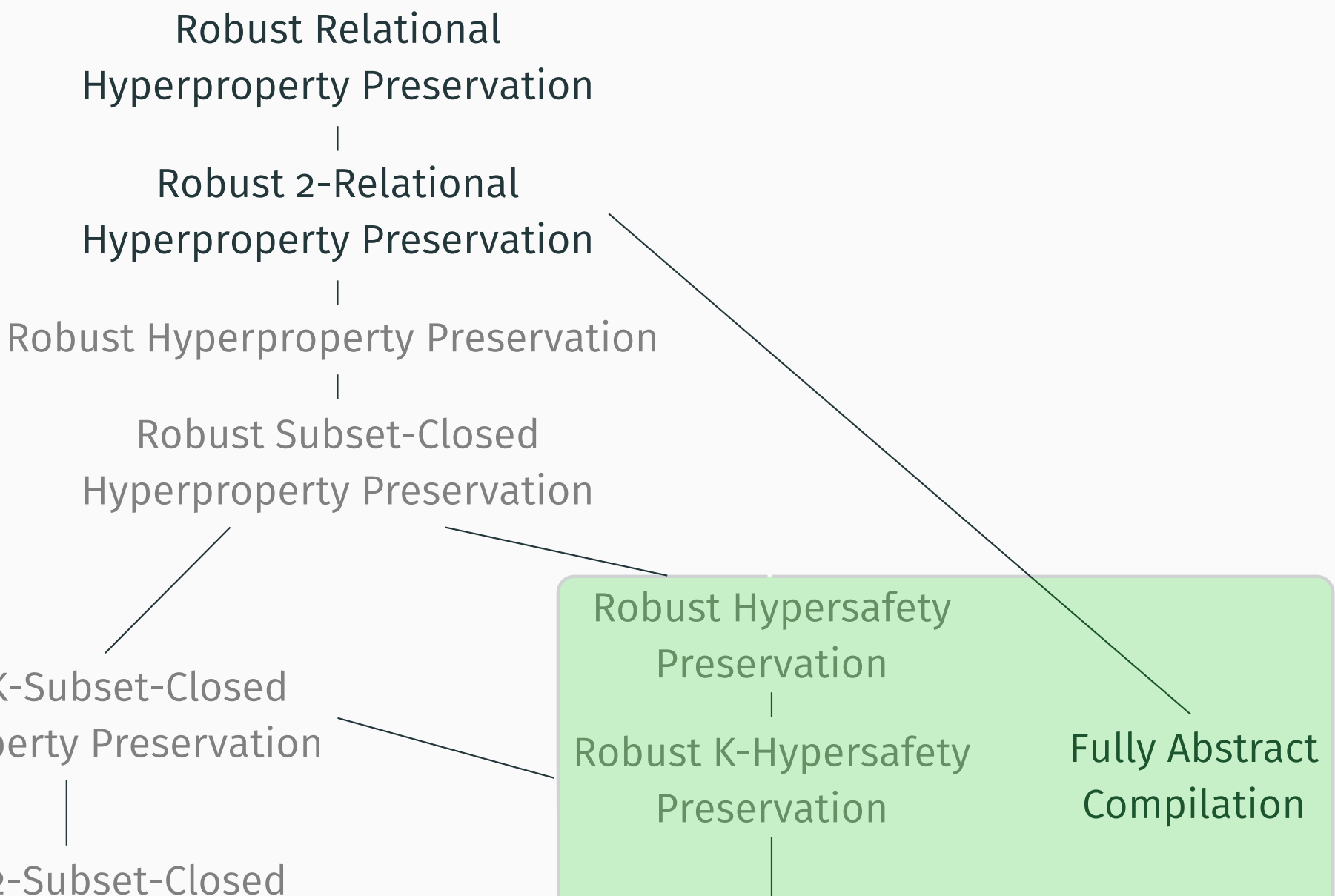

Robust Relational Hyperproperty Preservation

Definition: (HRC)

$$[\![\cdot]\!] \in \mathrm{HRC} \stackrel{\text{def}}{=} \forall \mathbb{C}_t, \mathrm{P}_s. \exists \mathbb{C}_s. \beta$$

$$\beta \in \mathtt{Behav}\left(\mathbb{C}_t\left[[\![\mathrm{P}_s]\!]\right]\right)$$

$$\iff \beta \in \mathtt{Behav}\left(\mathbb{C}_s\left[\mathrm{P}_s\right]\right)$$

Robust Relational Hyperproperty Preservation

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$$\beta \in \mathtt{Behav}\left(\mathbb{C}_t\left[[\![P_s]\!]\right]\right)$$
$$\iff \beta \in \mathtt{Behav}\left(\mathbb{C}_s\left[P_s\right]\right)$$

Robust 2-Relational Hyperproperty Preservation

Definition: (RRHP)

$$[\![\cdot]\!] \in \mathrm{RRHP} \stackrel{\text{def}}{=} \forall \mathbb{C}_t, \exists \mathbb{C}_s. \forall \mathrm{P}_s. \beta$$

$$\left(\beta \in \mathtt{Behav}\left(\mathbb{C}_t\left[[\![\mathrm{P}_s]\!]\right]\right) \iff \beta \in \mathtt{Behav}\left(\mathbb{C}_s\left[\mathrm{P}_s\right]\right) \right)$$

Robust 2-Relational Hyperproperty Preservation

Definition: (R2RHP**)**

$$[\![\cdot]\!] \in \text{R2RHP} \stackrel{\text{def}}{=} \forall \mathbb{C}_t, \exists \mathbb{C}_s. \forall \, P_s, P'_s. \, \beta$$

$$\left(\beta \in \text{Behav}\left(\mathbb{C}_t\left[[\![P_s]\!]\right]\right) \iff \beta \in \text{Behav}\left(\mathbb{C}_s\left[P_s\right]\right) \right)$$

$$\text{and} \quad \left(\beta \in \text{Behav}\left(\mathbb{C}_t\left[[\![P'_s]\!]\right]\right) \iff \beta \in \text{Behav}\left(\mathbb{C}_s\left[P'_s\right]\right) \right)$$