**Definition** (Series composition)

Let  $\mathbf{d}: \mathbf{P} \to \mathbf{Q}$  and  $\mathbf{e}: \mathbf{Q} \to \mathbf{R}$  be design problems. We define their *series* composition  $(\mathbf{d}, \mathbf{e}): \mathbf{P} \to \mathbf{R}$  as:

$$(\mathbf{d}_{9}^{\circ}\mathbf{e}): \mathbf{P}^{\mathrm{op}} \times \mathbf{R} \to_{\mathbf{Pos}} \mathbf{Bool},$$
 
$$\langle p^{*}, r \rangle \mapsto \bigvee_{q \in \mathbf{Q}} \mathbf{d}(p^{*}, q) \wedge \mathbf{e}(q^{*}, r).$$

Alternatively, rather than taking the "or" ( $\vee$ ) over an element q, we can iterate over pairs  $q_1, q_2$  such that  $q_1 \leq q_2$ :

$$(\mathbf{d}_{9}^{\circ}\mathbf{e}): \mathbf{P}^{\mathrm{op}} \times \mathbf{R} \to_{\mathbf{Pos}} \mathbf{Bool},$$

$$\langle p^{*}, r \rangle \mapsto \bigvee_{\substack{q_{1} \leq q_{2}, q_{1}, q_{2} \in \mathbf{Q}}} \mathbf{d}(p^{*}, q_{1}) \wedge \mathbf{e}(q_{2}^{*}, r).$$