

$$\begin{aligned}
\nabla v_\pi(s) &= \nabla \left[\sum_a \pi(a|s) q_\pi(s, a) \right], \quad \text{for all } s \in \mathcal{S} && \text{(Exercise 3.16)} \\
&= \sum_a \left[\nabla \pi(a|s) q_\pi(s, a) + \pi(a|s) \nabla q_\pi(s, a) \right] \quad \text{(product rule of calculus)} \\
&= \sum_a \left[\nabla \pi(a|s) q_\pi(s, a) + \pi(a|s) \nabla \sum_{s', r} p(s', r|s, a) (r + v_\pi(s')) \right] \\
&\hspace{25em} \text{(Exercise 3.17 and Equation 3.2)} \\
&= \sum_a \left[\nabla \pi(a|s) q_\pi(s, a) + \pi(a|s) \sum_{s'} p(s'|s, a) \nabla v_\pi(s') \right] && \text{(Eq. 3.4)} \\
&= \sum_a \left[\nabla \pi(a|s) q_\pi(s, a) + \pi(a|s) \sum_{s'} p(s'|s, a) \right. \\
&\hspace{15em} \left. \sum_{a'} [\nabla \pi(a'|s') q_\pi(s', a') + \pi(a'|s') \sum_{s''} p(s''|s', a') \nabla v_\pi(s'')] \right] \quad \text{(unrolling)} \\
&= \sum_{x \in \mathcal{S}} \sum_{k=0}^{\infty} \text{Pr}(s \rightarrow x, k, \pi) \sum_a \nabla \pi(a|x) q_\pi(x, a),
\end{aligned}$$