5

5.1

We have $M = (Q, \Sigma, \delta)$ and $\pi = \{H_i\}_{i \in I}$ a admissible partion of Q. If M is complete then for all $i \in I$ and for all $a \in \Sigma$ there exists **exactly one** partion such that for $j \in I$ $H_i\delta_a \subseteq H_j$. By definition of π (Lemma 3.48) there exists **at least one** $j \in I$ with $H_i\delta_a \subseteq H_j$. Notice $H_i\delta_a \neq \emptyset$ because M is complete.
We show that there only exists **exactly one** $j \in I$. Suppose there exists $j, k \in I$ with $H_i\delta_a \subseteq H_{j,k}$ for all $a \in \Sigma$ and $j \neq k$. We choose an arbitray $q \in H_i$ then the following must hold:

$$q\delta_a = q_j \in H_j$$
$$q\delta_a = q_k \in H_k$$

Notice $q_j \neq q_k$ because $H_j \cap H_k = \emptyset$. This is a contraction because $q\delta_a$ is not right unique anymore.

5.2

We do a case distinction.
$\pi = \{Q\}$: Notice we have only one equivalence class $H_1 = Q$. Hence, all states are related by the admissible relation R. Thus, $(q, q') \in R | \forall q, q' \in Q$ and also $(qs, q's) \in R$ for all $s \in S$ with $qs, q's \neq \emptyset$. Therefore $H_1 s = H_1$ for all $s \in S$.
$\pi = [q] | \ \forall q \in Q$:

- cases for only one admissible partition and for $|Q|$ admissible partitions
- one equivalence class $\pi = H_1 \implies |qS| = 1$:
  - all states are related, $(q, q') \in R | \forall q, q' \in Q$
  - $q \in H_1$ for all $q \in Q$ and therefore $Q = H_1 = [q]_R$
  - $H_1 s = H_1$
  - $qs = q'$ for all $q, q' \in H_1$

  - suppose $q' \notin H_i$, thus $q \notin Q$ and therefore not included in the transformation semigroup

- $|Q|$ equivalence classes $\implies qS = Q$:
  - $|Q|$ equivalence classes implies each state has own equivalence classes, $R = \{(q_i, q_i) | i \in [|Q|\}$
  - $qs = q$ for all $q \in Q$ and $s \in S$ with $q \in H_i, i \in [|Q|]$
  - suppose $qs = q'$ with $q \neq q'$ then $(q, q') \in R$ which contradicts first statement

5.3

5.4