Theorem

Let L be an infinite regular language. Let p be the number of states in a deterministic finite automaton that recognises L. Then any string s in L of length at least $p = |s|$ can be broken into three substrings $s = xyz$ such that:

- $|y| > 0$,
- $|xy| \leq p$, and
- $xy^iz \in L$ for all $i \in \mathbb{N}_0$.

Rationale

Once we read p characters from s, we must have visited some state twice[1]. Suppose q is a state we visit twice, and call y the substring of s that we read between the two visits.
When we can delete y from s and the automaton must accept this new string also. Likewise we can repeat y any number of times to create a new string that must also be accepted.
Note the automaton essentially forgets the path it took to a given state – once it arrives at a given state it can't remember how it got there.

Example

Non-regular example

$$L = \{0^i1^i | i \in \mathbb{N}_0\}$$
$$s = 0^p1^p = xyz$$
$$|xy| \leq p \Rightarrow y = 0^n, n \in \mathbb{N}$$
$$\Rightarrow 0^{p-n}0^{2n}1^n \in L$$

That's a contradiction.

References

[1] At least one state at least twice.