

# Lecture 3: Finite Automata

## Administrivia

- Everyone should now be registered electronically using the link on our webpage. If you haven't, do so today!
- I'd like to have teams formed by next Wednesday at the latest.
- Homework #2 is posted; due next Tuesday.
- Please fill out the background survey linked to on the homework page.

# Classical Pattern-Matching Implementation

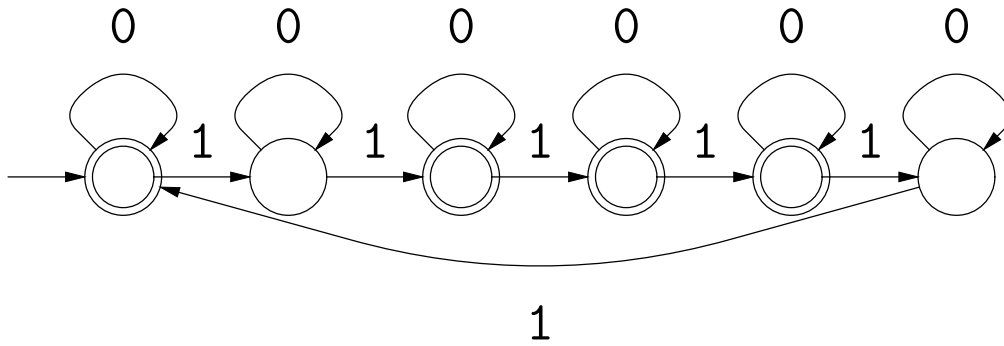
- For compilers, can generally make do with “classical” regular expressions.
- Implementable using *finite(-state) automata* or *FAs*. (“Finite state” = “finite memory”).
- Classical construction:

regular expression  $\Rightarrow$  nondeterministic FA (NFA)  
 $\Rightarrow$  deterministic FA (DFA)  $\Rightarrow$  table-driven program.

## Review: FA operation

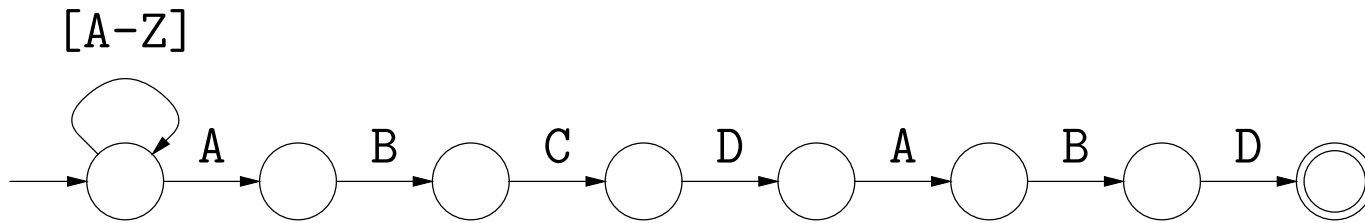
- A FA is a graph whose nodes are **states (of memory)** and whose edges are **state transitions**. There are a finite number of nodes.
- One state is the designated **start state**.
- Some subset of the nodes are **final states**.
- Each transition is labeled with a set of symbols (characters, etc.) or  $\epsilon$ .
- A FA **recognizes** a string  $c_1c_2 \cdots c_n$  if there is a path (sequence of edges) from the start state to a final state such that the labels of the edges in sequence, aside from  $\epsilon$  edges, respectively contain  $c_1, c_2, \dots, c_n$ .
- If the edges leaving any node have disjoint sets of characters and if there are no  $\epsilon$  nodes, FA is a DFA, else an NFA.

## Example: What does this DFA recognize?



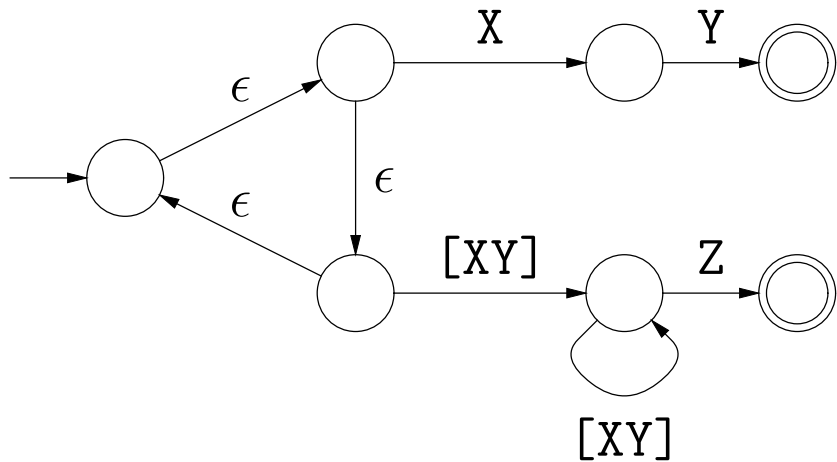
What is the simplest equivalent NFA you can think of?

## Example: What does this NFA recognize?



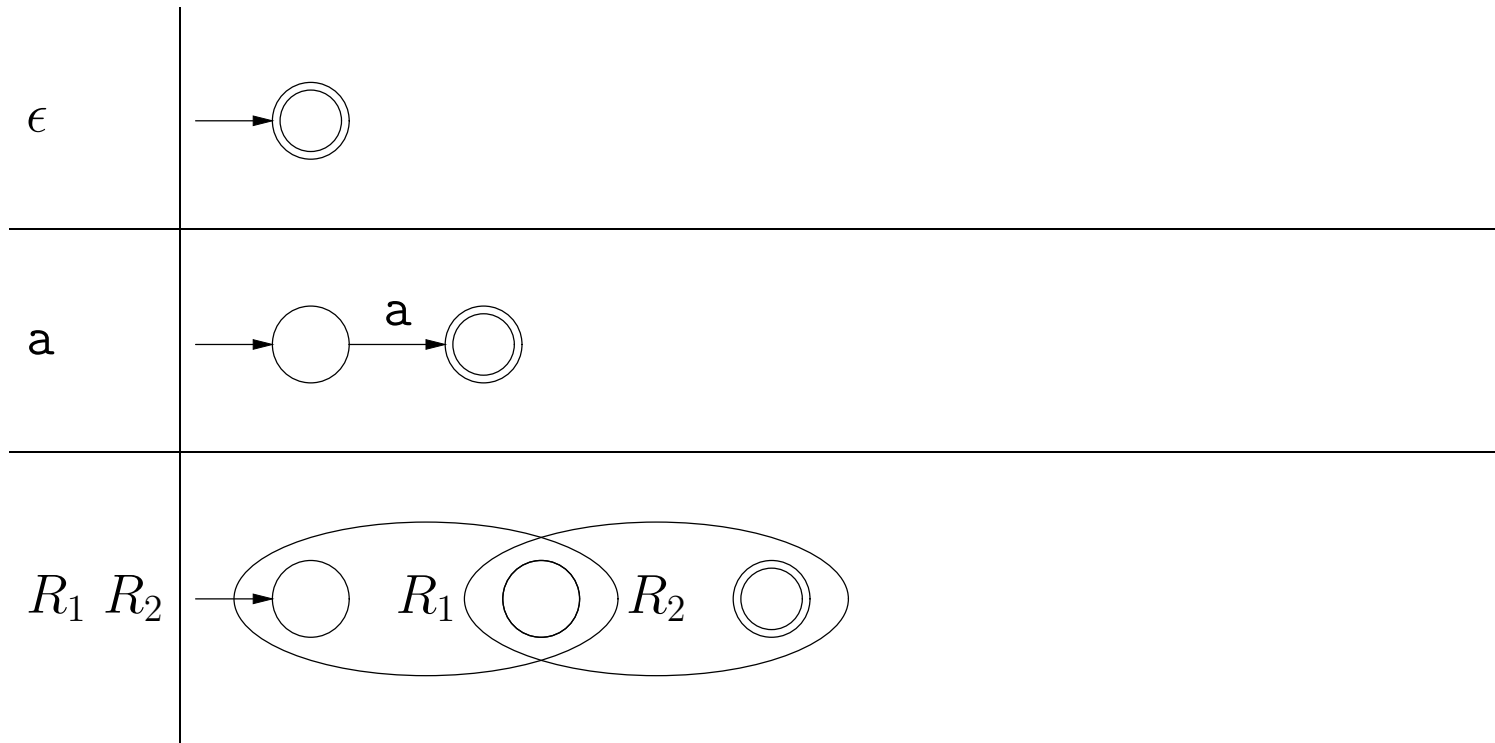
What is the simplest equivalent DFA you can think of?

## Example: What does this NFA recognize?

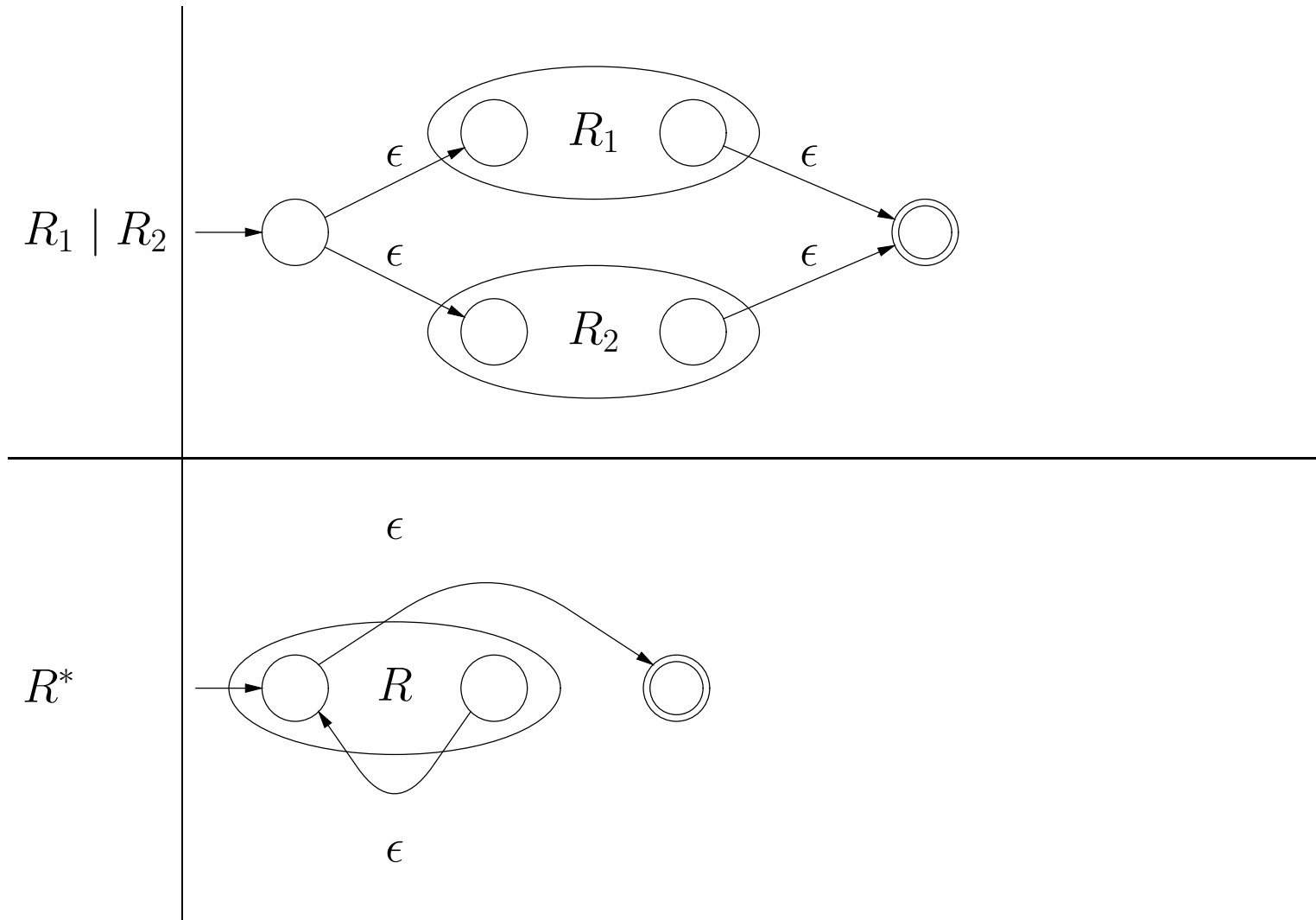


What is the simplest equivalent DFA you can think of?

# Review: Classical Regular Expressions to NFAs (I)



# Review: Classical Regular Expressions to NFAs (II)





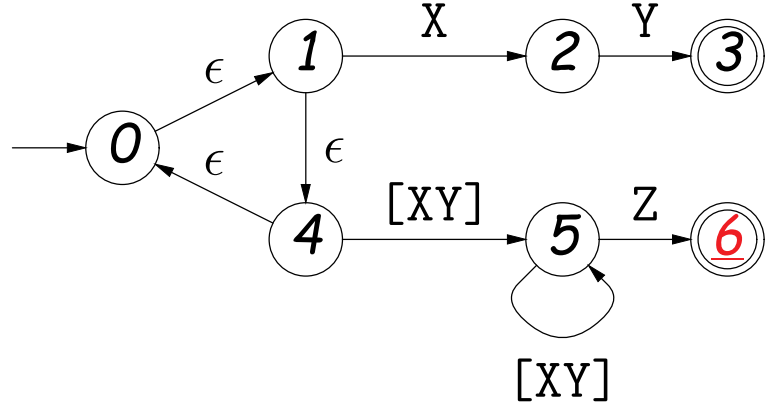
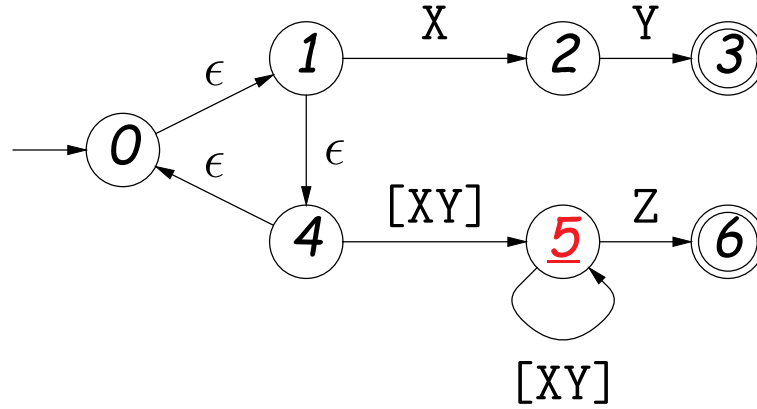
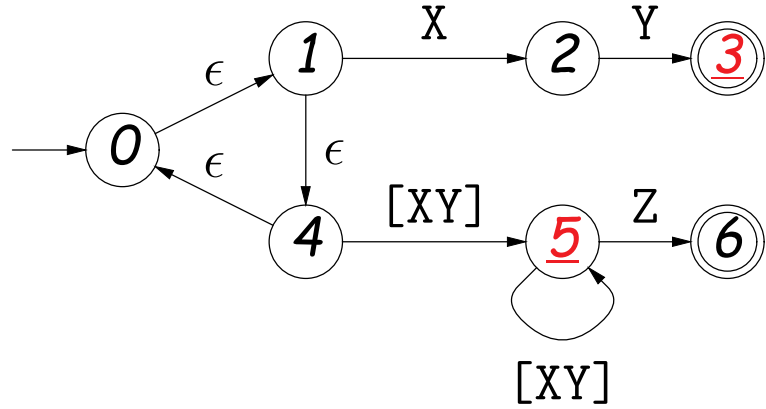
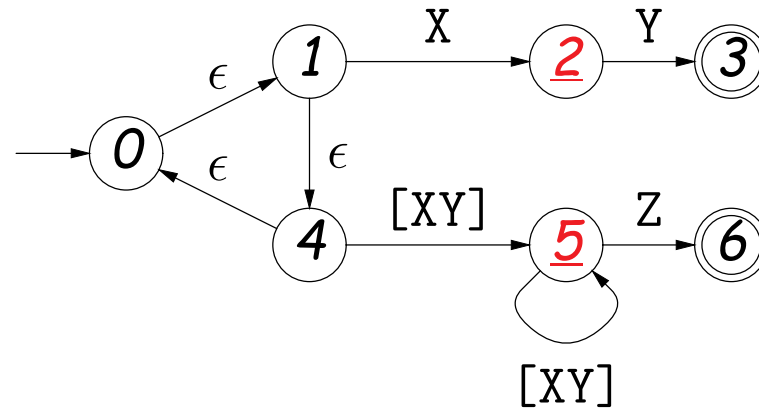
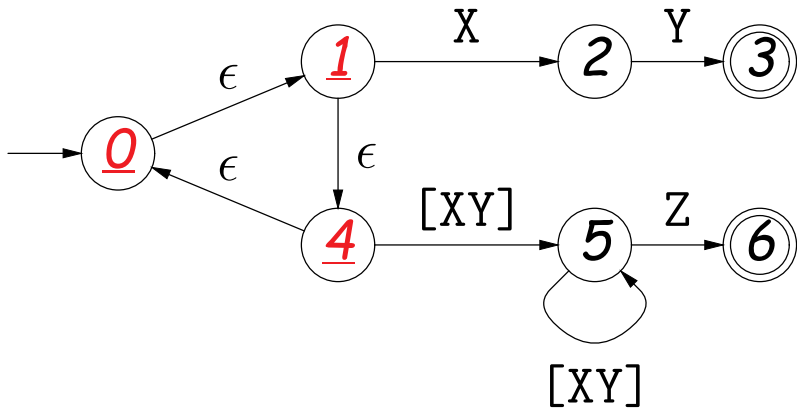
# Extensions?

- How would you translate  $\phi$  (the empty language, containing no strings) into an FA?
- How could you translate 'R?' into an NFA?
- How could you translate 'R+' into an NFA?
- How could you translate ' $R_1|R_2|\dots|R_n$ ' into an NFA?

# Example of Conversion

How would you translate  $((ab)^* | c)^*$  into an NFA?

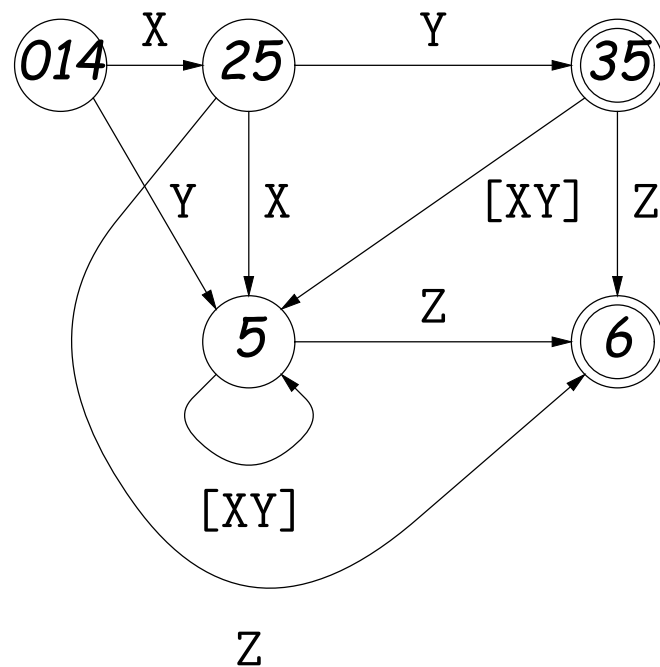
# Abstract Implementation of NFAs



String: XYYZ

## Review: Converting to DFAs

- **OBSERVATION:** The **set of states** that are marked (colored red) changes with each character in a way that depends only on the set and the character.
- In other words, machine on previous slide acted like this DFA:



# DFAs as Programs

- Can realize DFA in program with control structure:

```
state = INITIAL;
for (s = input; *s != '\0'; s += 1) {
    switch (state):
    case INITIAL:
        if (*s == 'a') state = A_STATE; break;
    case A_STATE:
        if (*s == 'b') state = B_STATE; else state = INITIAL; break;
    ...
}
return state == FINAL1 || state == FINAL2;
```

- Or with data structure (table driven):

```
state = INITIAL;
for (s = input; *s != '\0'; s += 1)
    state = transition[state][s];
return isfinal[state];
```

# What Flex Does

- Flex program specification is giant regular expression of the form  $R_1|R_2|\dots|R_n$ , where none of the  $R_i$  match  $\epsilon$ .
- Each final state labeled with some action.
- Converted, by previous methods, into a table-driven DFA.
- But, this particular DFA is used to recognize *prefixes* of the (remaining) input: initial portions that put machine in a final state.
- Which final state(s) we end up in determine action. To deal with multiple actions:
  - Match *longest* prefix ("maximum munch").
  - If there are multiple matches, apply *first* rule in order.

# How Do They Do It?

- How can we use a DFA to recognize longest match?
- How can we use DFA to act on first of equal-length matches?
- How can we use a DFA to handle the  $R_1/R_2$  pattern (matches just  $R_1$  but only if followed by  $R_2$ , like  $R_1(=?R_2)$  in Python)?