- Previous lecture:
  - Why use OOP?
  - Attributes for properties and methods
  - Inheritance: extending a superclass
- Today's lecture:
  - OOP: Overriding methods in superclass
  - New topic: Recursion
- Announcement:
  - Final exam on Fri, Dec 7th, at 9am. Email Randy Hess (rbh27) now if you have an exam conflict. Specify your entire exam schedule (course numbers/contacts and the exam times). We must have this information by Nov 25th.

Make TrickDie a subclass of Die

```
classdef Die < handle
 properties (Access=private)
  sides=6;
  top
 end
 methods
  function D = Die(…)  …
  function roll(…)  …
  function disp(…)  …
  function s = getSides(…)  …
  function t = getTop(…)  …
 end
 methods (Access=protected)
  function setTop(…)  …
 end
end
```

```
classdef TrickDie < Die

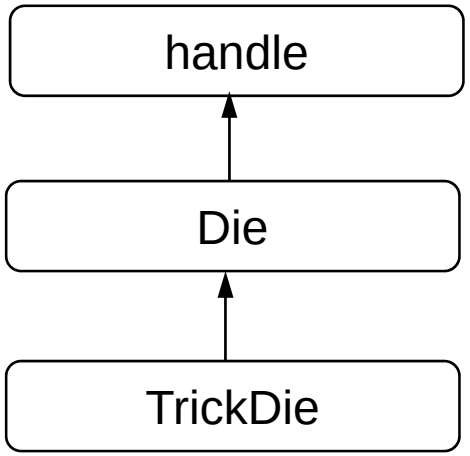
 properties (Access=private)
  favoredFace
  weight=1;
 end

 methods
  function D = TrickDie(…)  …
  function f=getFavoredFace(…)…
  function w = getWeight(…)  …
 end

end
```

Inheritance

Inheritance relationships are shown in a *class diagram*, with the arrow pointing to the parent class



An ***is-a*** relationship: the child ***is a*** more specific version of the parent. Eg., a trick die *is a* die.

Multiple inheritance: can have multiple parents ← e.g., Matlab

Single inheritance: can have one parent only ← e.g., Java

Inheritance

- Allows programmer to *derive* a class from an existing one
- Existing class is called the *parent class*, or *superclass*
- Derived class is called the *child class* or *subclass*
- The child class *inherits* the (public and protected) members defined for the parent class
- Inherited trait can be *accessed as though it was **locally** defined*

Must call the superclass' constructor

- In a subclass' constructor, call the superclass' constructor before assigning values to the subclass' properties.
- Calling the superclass' constructor cannot be conditional: explicitly make one call to superclass' constructor

Syntax

```
classdef Child < Parent

 properties
  propC
 end

 methods

  function obj = Child(argC, argP)

     obj@Parent(argP)

     obj.propC = argC;
  end

  ...
 end

end
```

See constructor in **`TrickDie.m`**

Which components get "inherited"?

- public components get inherited
- private components exist in object of child class, but cannot be directly accessed in child class $\Rightarrow$ we say they are not inherited
- Note the difference between inheritance and existence!

`protected` attribute

- Attributes dictate which members get inherited

- **`private`**
  - Not inherited, can be *accessed* by local class only
- **`public`**
  - Inherited, can be *accessed* by all classes
- **`protected`**
  - Inherited, can be *accessed* by subclasses

- *Access*: access as though defined locally
- All members from a superclass *exist* in the subclass, but the **`private`** ones cannot be *accessed* directly—can be accessed through inherited (public or protected) methods

```
td = TrickDie(2, 10, 6);
disp(td.sides);
% disp statement is incorrect because
```

A Property sides is private.

B Property sides does not exist in the TrickDie object.

C Both a, b apply

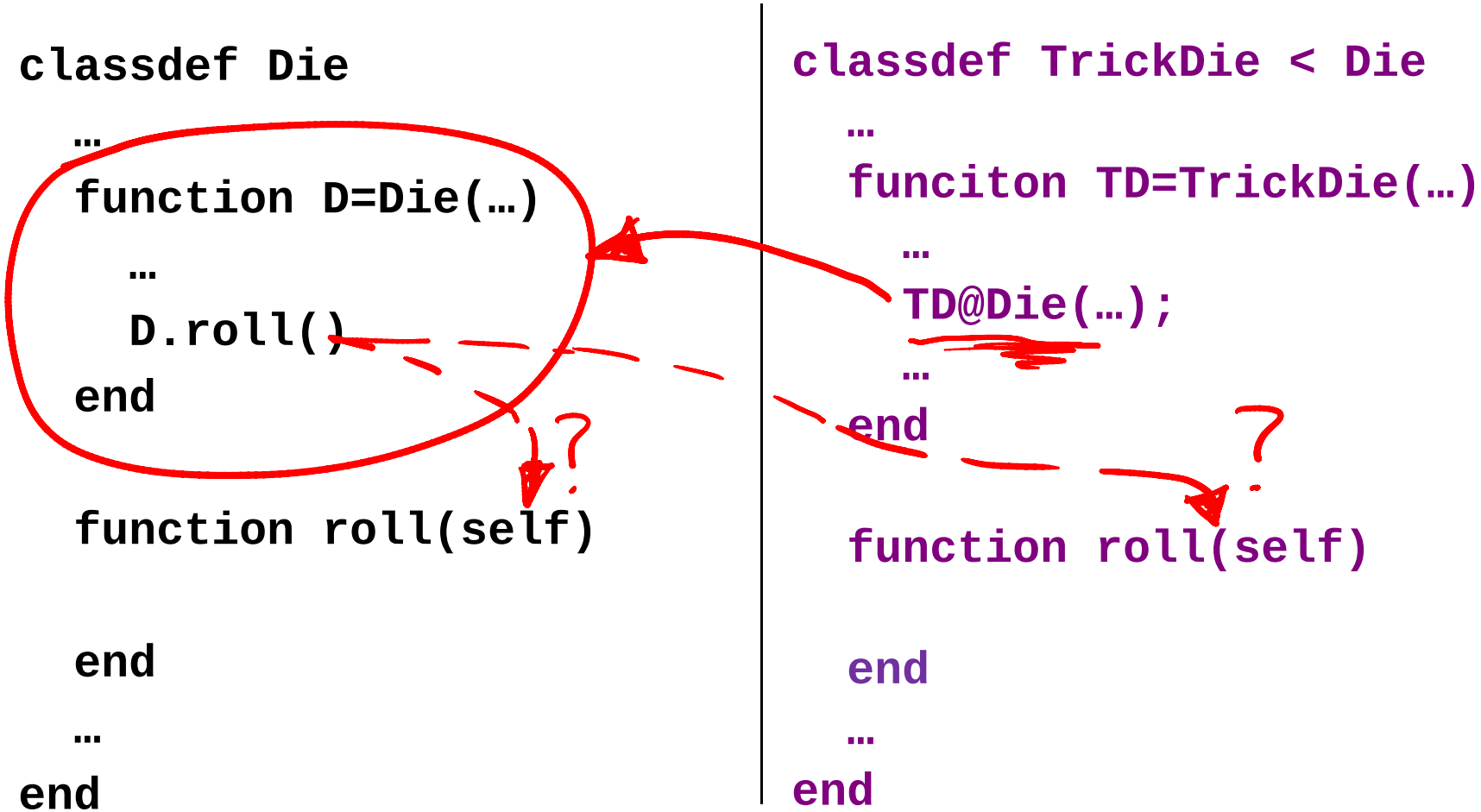
Overriding methods

- Subclass can *override* definition of inherited method
- New method in subclass has the same name (but has different method body)

See method **`roll`** in **`TrickDie.m`**

Overridden methods: which version gets invoked?

To create a TrickDie: call the TrickDie constructor, which calls the Die constructor, which calls the roll method. Which roll method gets invoked?



Overriding methods

- Subclass can *override* definition of inherited method
- New method in subclass has the same name (but has different method body)
- Which method gets used??

  *The **object** that is used to invoke a method determines which version is used*
- Since a TrickDie object is calling method **`roll`**, the TrickDie's version of **`roll`** is executed
- In other words, the method most specific to the type (class) of the object is used

Accessing superclass' version of a method

- Subclass can override superclass' methods
- Subclass can access superclass' version of the method

Syntax

```
classdef Child < Parent

 properties
  propC
 end

 methods
  …

  function x= method(arg)

      y= method@Parent(arg);

      x = … y … ;
  end

  …
 end
end
```

See method **`disp`** in **`TrickDie.m`**

Important ideas in inheritance

- Keep common features as high in the hierarchy as reasonably possible
- Use the superclass' features as much as possible
- "Inherited" $\Rightarrow$ "can be accessed as though declared locally"

  (`private` member in superclass *exists* in subclasses; they just cannot be accessed directly)
- Inherited features are continually passed down the line

(Cell) array of objects

- A cell array can reference objects of different classes

```
A{1}= Die();
A{2}= TrickDie(2,10);   % OK
```

- A simple array can reference objects of only one single class

```
B(1)= Die();
B(2)= TrickDie(2,10);   % ERROR
```

- (Assignment to B(2) above would work if we define a "convert method" in class TrickDie for converting a TrickDie object to a Die. We won't do this in CS1112.)

End of Matlab OOP in CS1112

OOP is a concept; in different languages it is expressed differently.

In CS (ENGRD) 2110 you will see Java OOP

Recursion

- The Fibonacci sequence is defined recursively:
  F(1)=1, F(2)=1,
  F(3)= F(1) + F(2) = 2
  F(4)= F(2) + F(3) = 3
  } F(k) = F(k-2) + F(k-1)
  It is defined in terms of itself; its definition invokes itself.

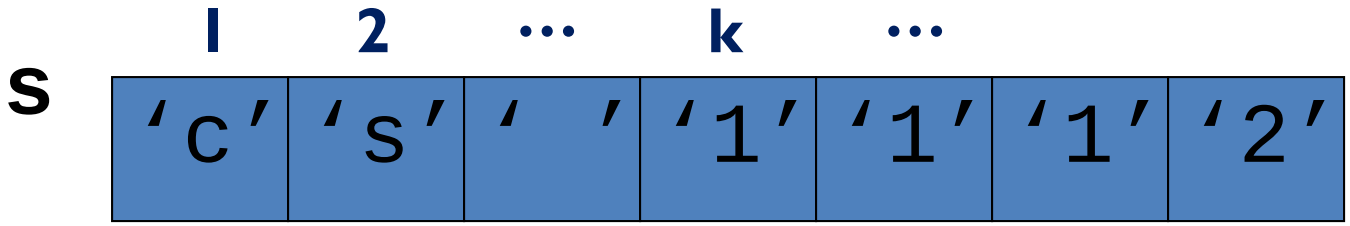
- Algorithms, and functions, can be recursive as well. I.e., a function can call itself.

- Example: remove all occurrences of a character from a string

  'gc aatc gga c ' → 'gcaatcggac'

Example: removing all occurrences of a character

- Can solve using iteration—check one character (one component of the vector) at a time



Subproblem 1:
Keep or discard s(1)

Subproblem 2:
Keep or discard s(2)

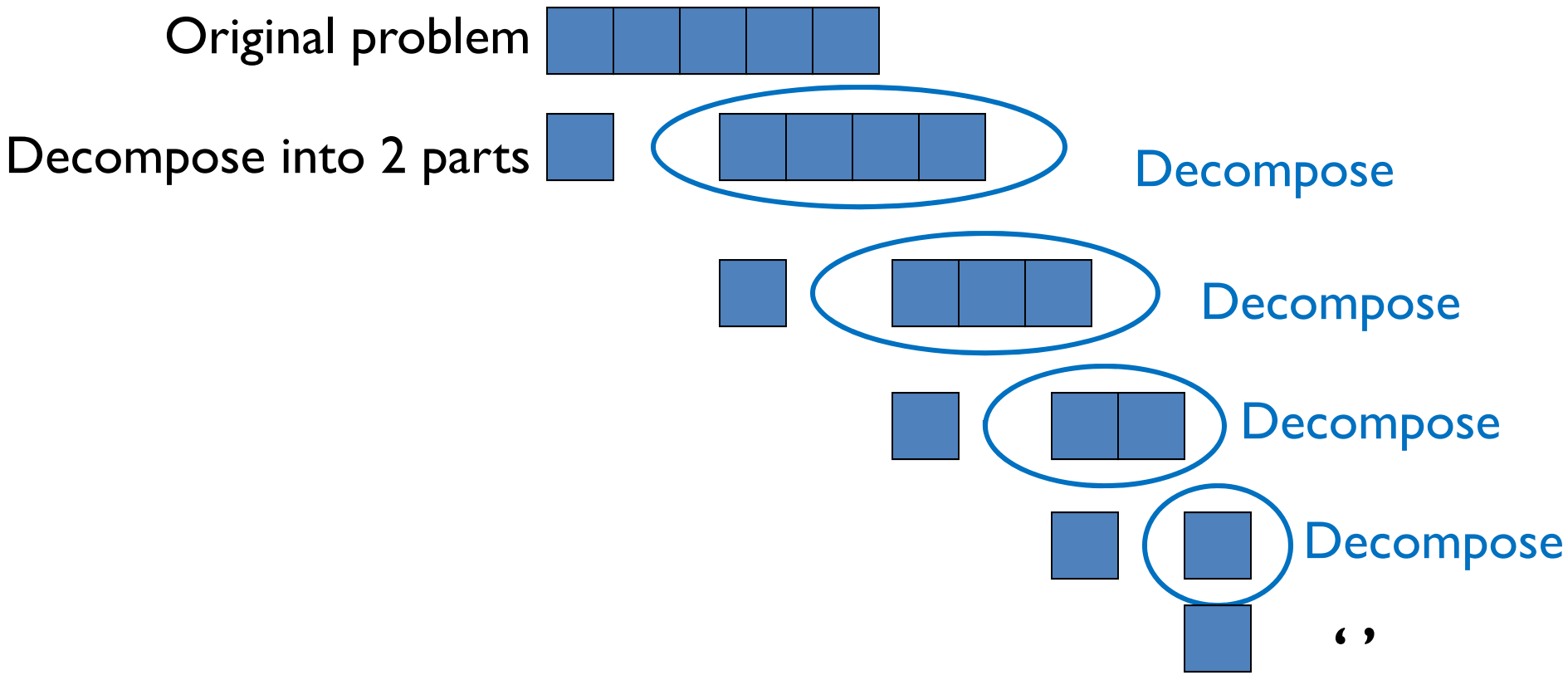
Subproblem k:
Keep or discard s(k)

Iteration:
Divide problem into sequence of equal-sized, identical subproblems

See **RemoveChar_loop.m**

Example: removing all occurrences of a character

- Can solve using ***recursion***
  - Original problem: remove all the blanks in string s
  - Decompose into two parts: 1. remove blank in s(1)
    2. remove blanks in s(2:length(s))



```
function s = removeChar(c, s)
% Return string s with character c removed

if length(s)==0  % Base case: nothing to do
    return
else




end
```

```
function s = removeChar(c, s)
% Return string s with character c removed

if length(s)==0  % Base case: nothing to do
    return
else
  if s(1)~=c



  else



  end
end
```

```
function s = removeChar(c, s)
% Return string s with character c removed

if length(s)==0  % Base case: nothing to do
    return
else
  if s(1)~=c
    % return string is
    % s(1) and remaining s with char c removed


  else



  end
end
```

```
function s = removeChar(c, s)
% Return string s with character c removed

if length(s)==0  % Base case: nothing to do
    return
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    % return string is just
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  end
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function s = removeChar(c, s)
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if length(s)==0  % Base case: nothing to do
    return
else
  if s(1)~=c
    % return string is
    % s(1) and remaining s with char c removed
    s= [s(1)                                    ];
  else
    % return string is just
    % the remaining s with char c removed

  end
end
```

```
function s = removeChar(c, s)
% Return string s with character c removed

if length(s)==0  % Base case: nothing to do
    return
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    % s(1) and remaining s with char c removed
    s= [s(1)                                    ];
  else
    % return string is just
    % the remaining s with char c removed
    s=                                          ;
  end
end
```

```
function s = removeChar(c, s)
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if length(s)==0  % Base case: nothing to do
    return
else
  if s(1)~=c
    % return string is
    % s(1) and remaining s with char c removed
    s= [s(1) removeChar(c, s(2:length(s)))];
  else
    % return string is just
    % the remaining s with char c removed
    s= removeChar(c, s(2:length(s)));
  end
end
```

```
function s = removeChar(c, s)
if length(s)==0
  return
else
  if s(1)~=c
    s= [s(1) removeChar(c, s(2:length(s)))];
  else
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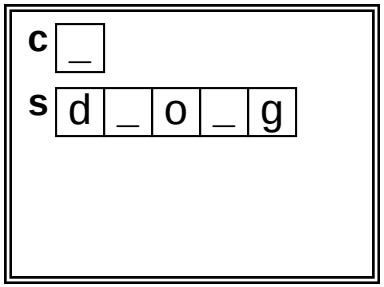
  end
end
```

s | d | _ | o | _ | g |

c | _ |

removeChar – 1st call



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end
```

s | d | _ | o | _ | g |

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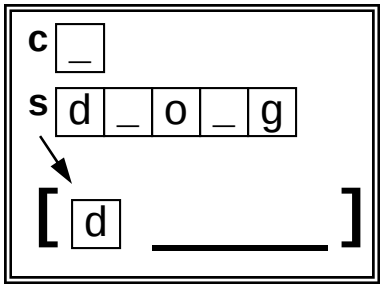
removeChar – 1st call



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else
  if s(1)~=c
    s= [s(1) removeChar(c, s(2:length(s)))];
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  end
end
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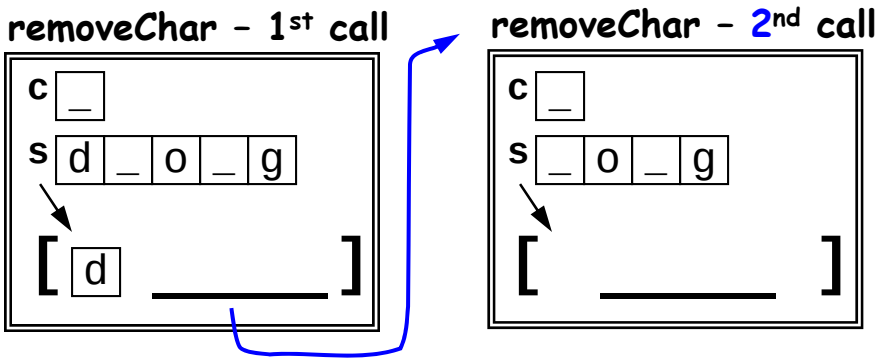
c | _ |



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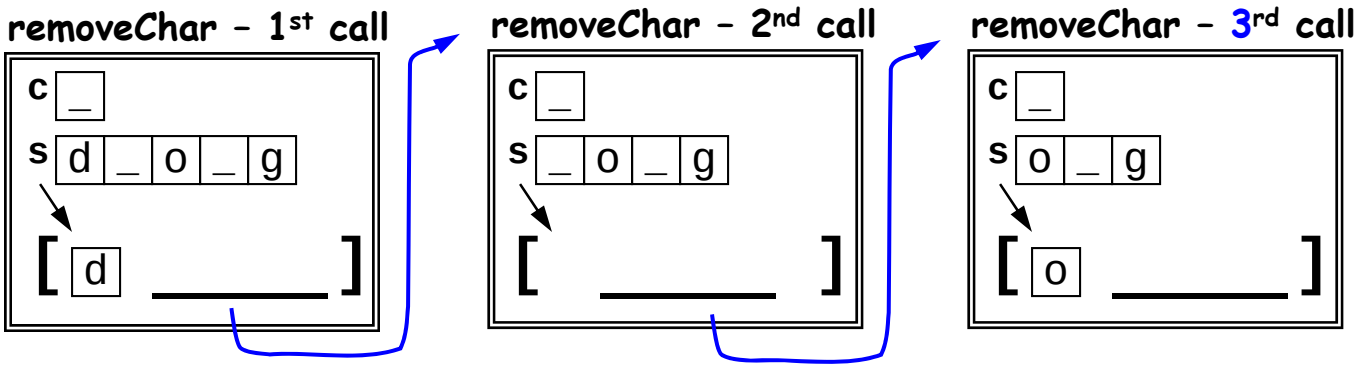

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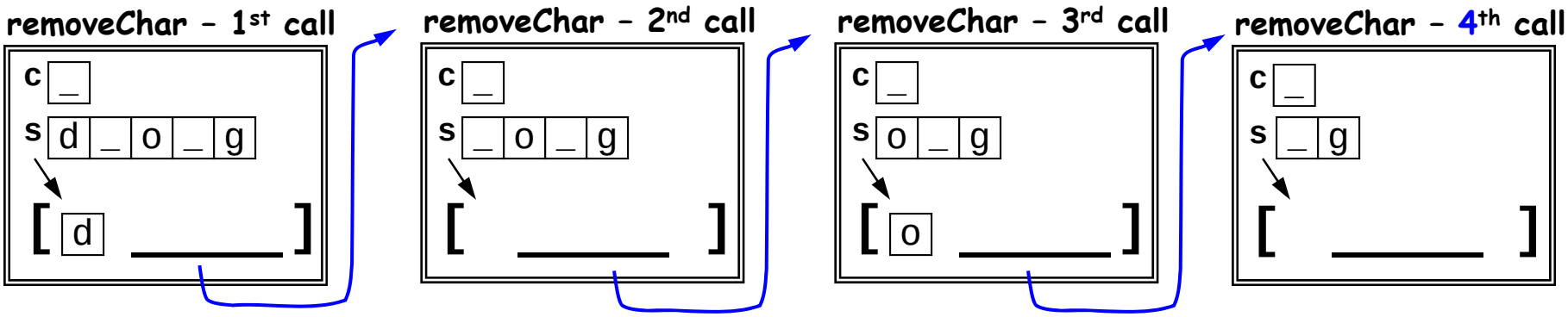

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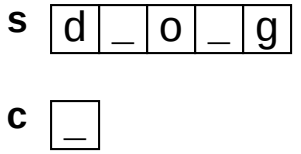

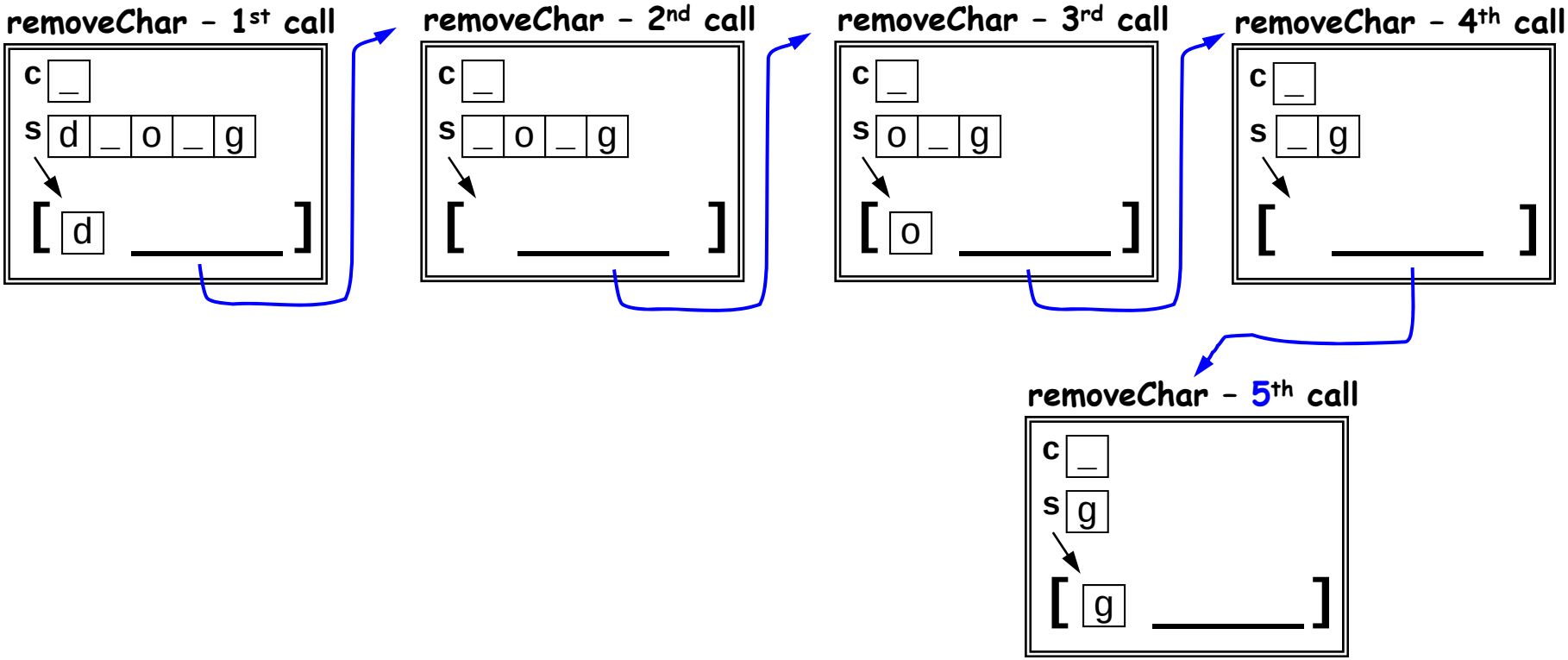

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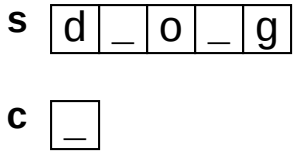

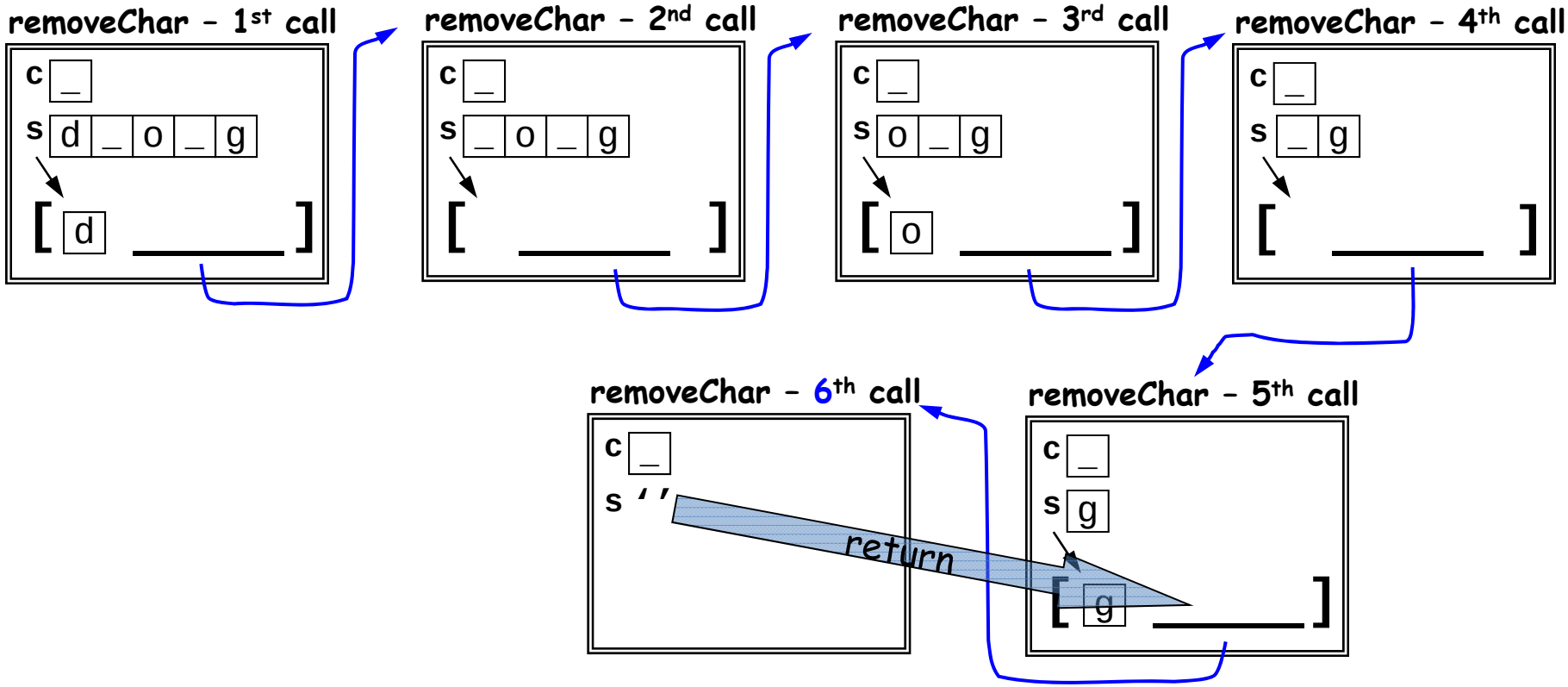

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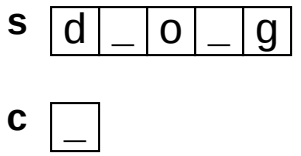

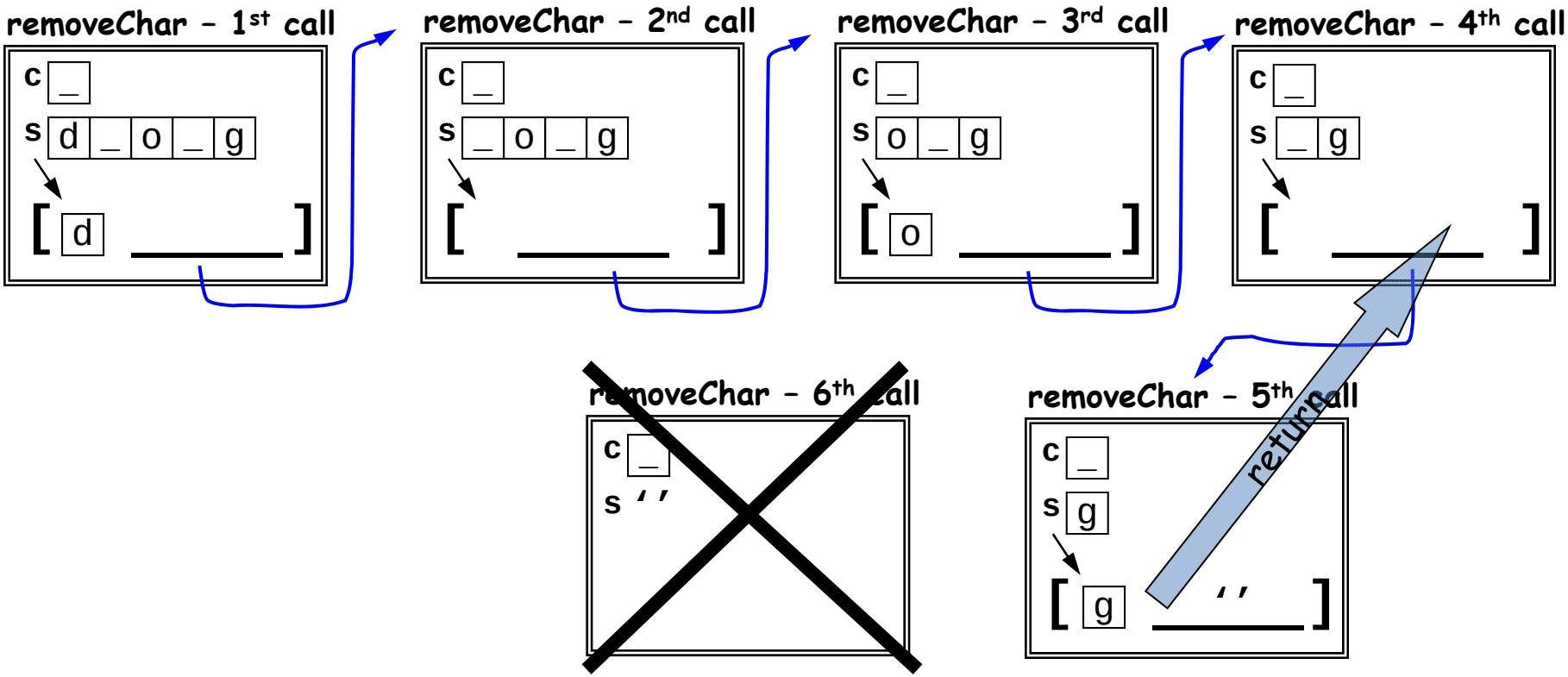

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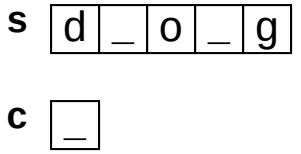

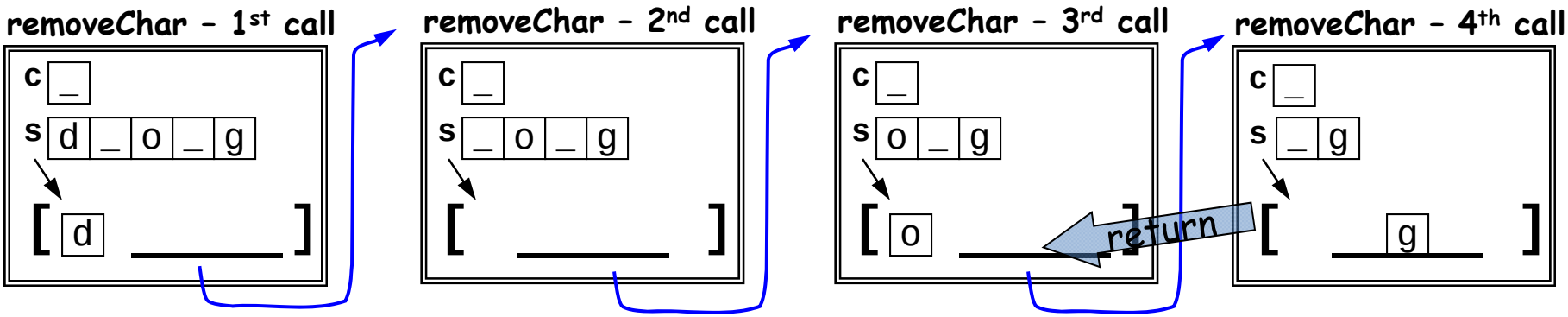

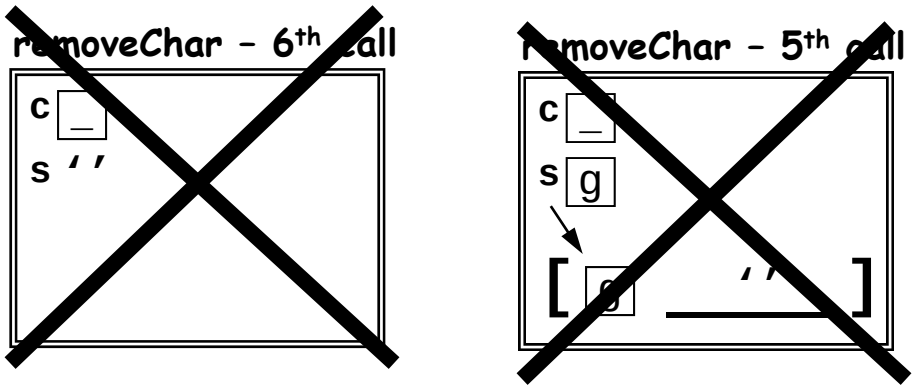

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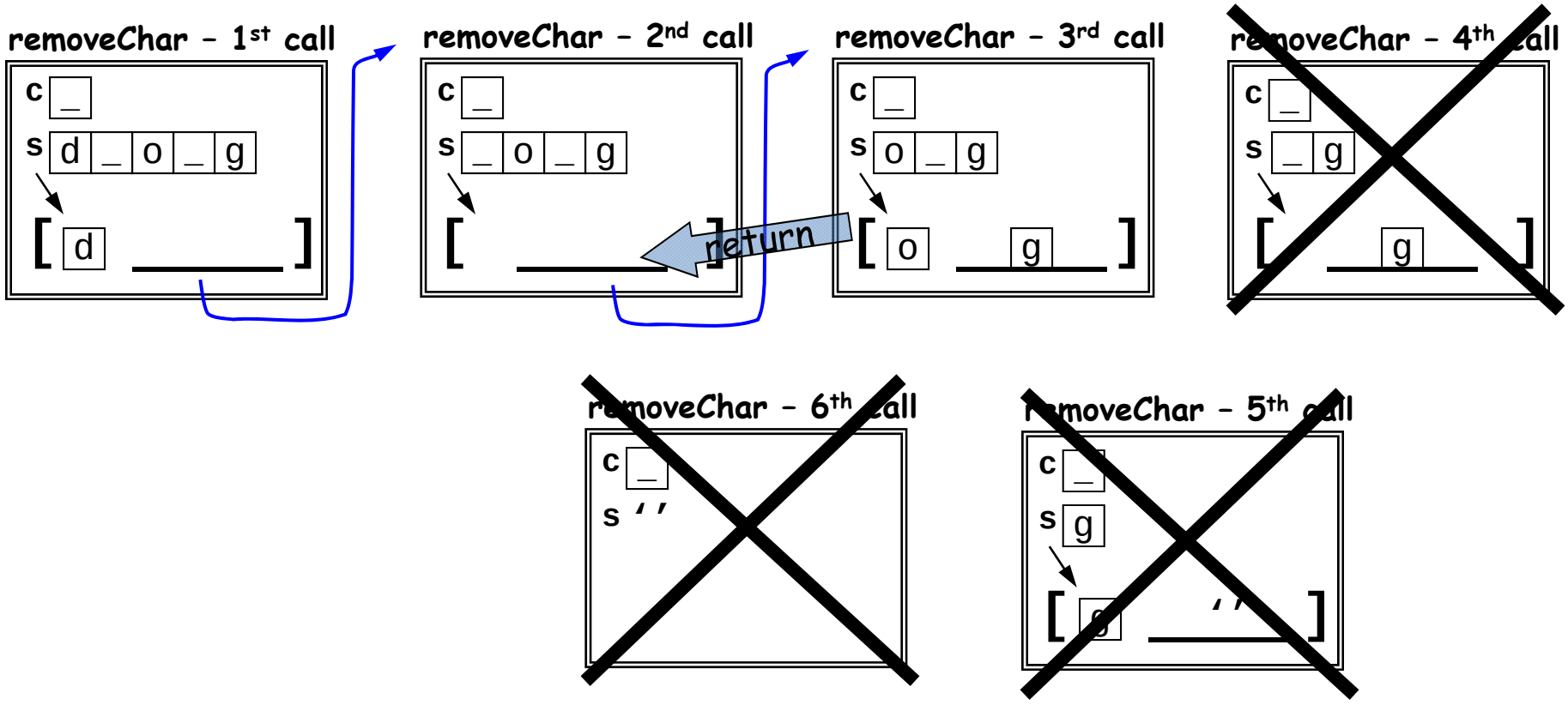

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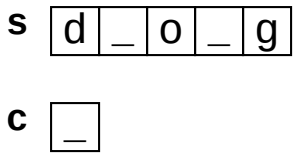

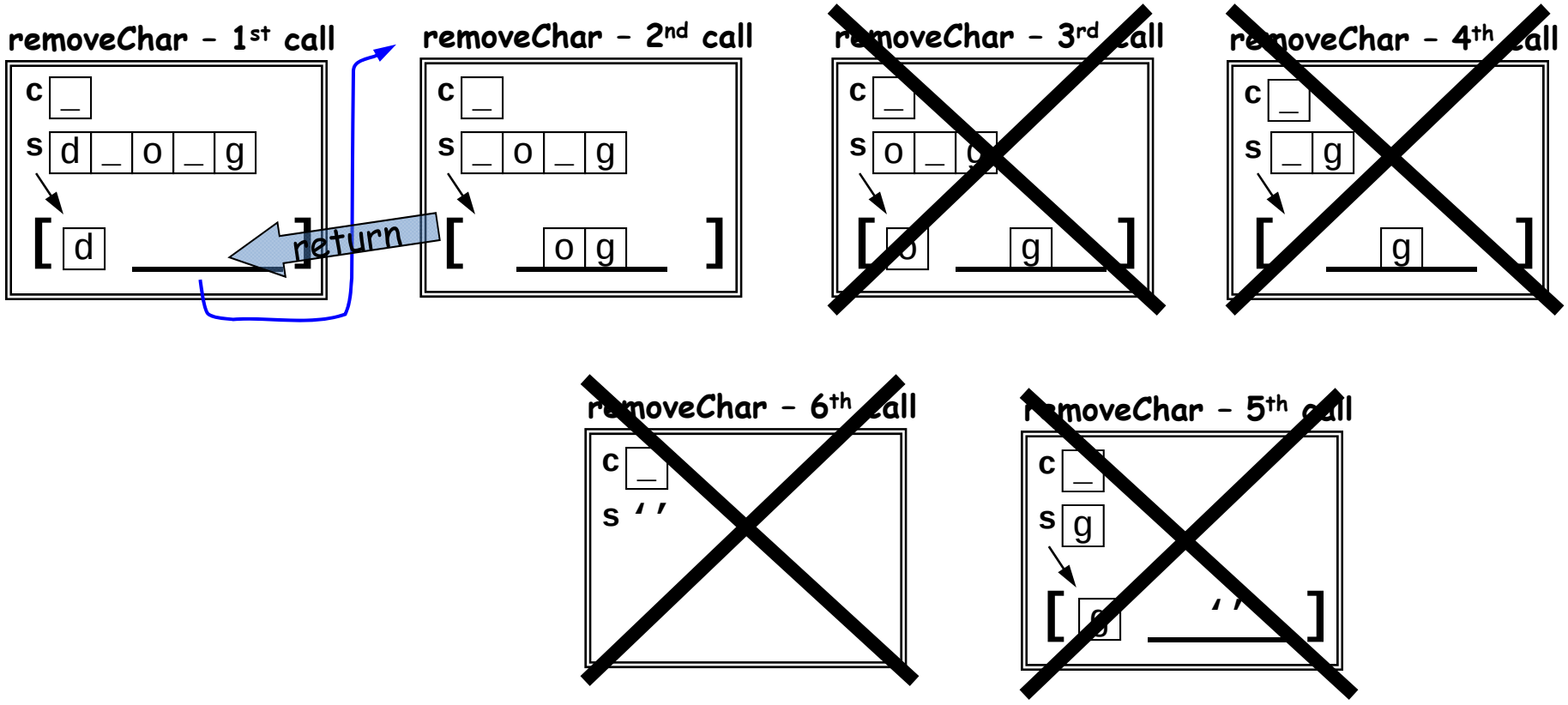

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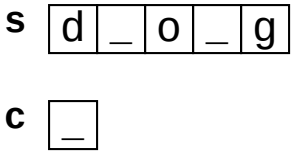

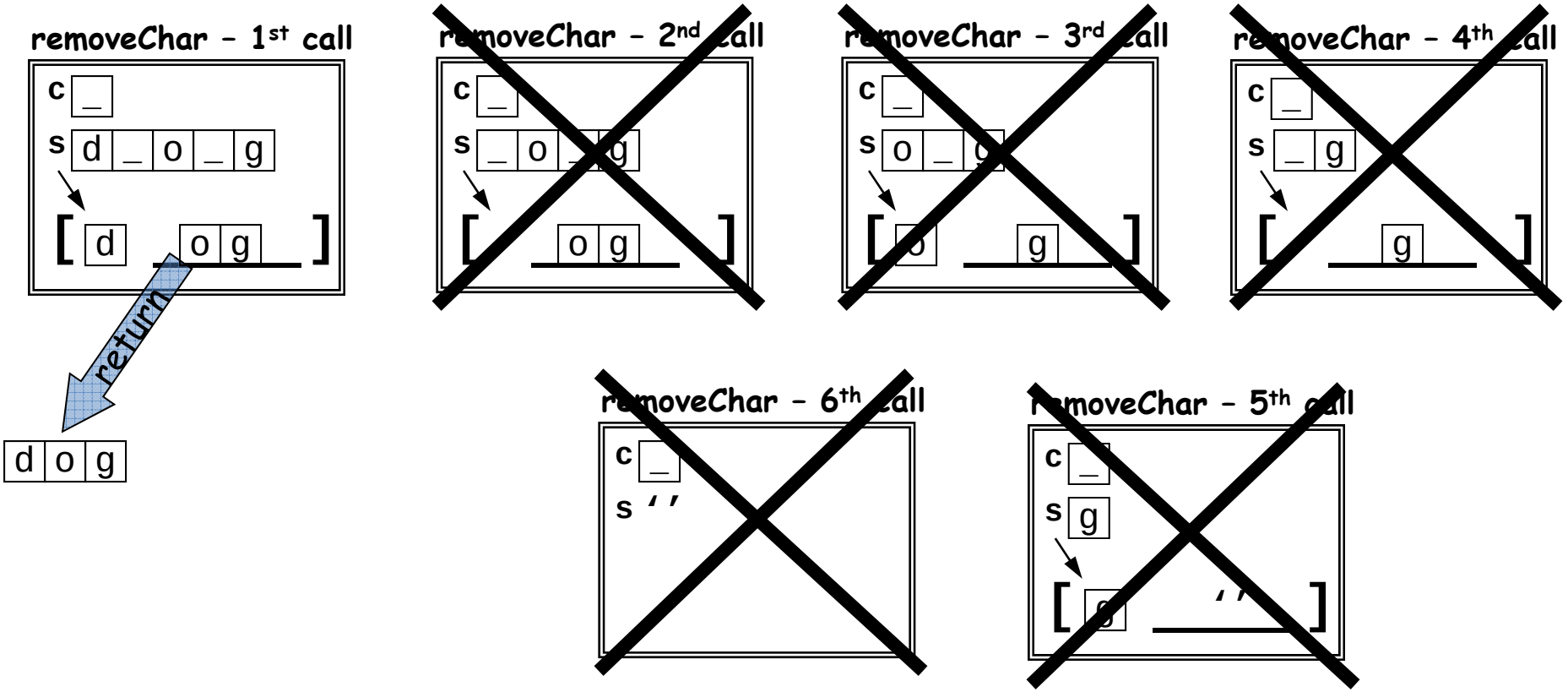

Key to recursion

- Must identify (at least) one base case, the "trivially simple" case
  - no recursion is done in this case
- The recursive case(s) must reflect progress towards the base case
  - E.g., give a shorter vector as the argument to the recursive call – see `removeChar`