Multi-Module Fully-Abstract Compilation

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Outline

Goal

- see secure compilation failures due to linking

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- see solutions to them (for PMA & Capability machines)

What is a Secure Compiler?

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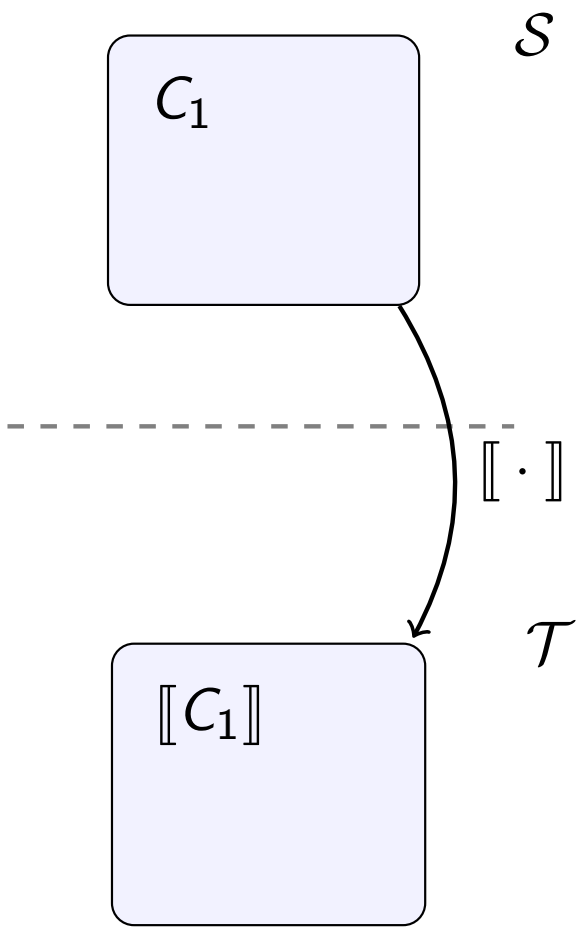

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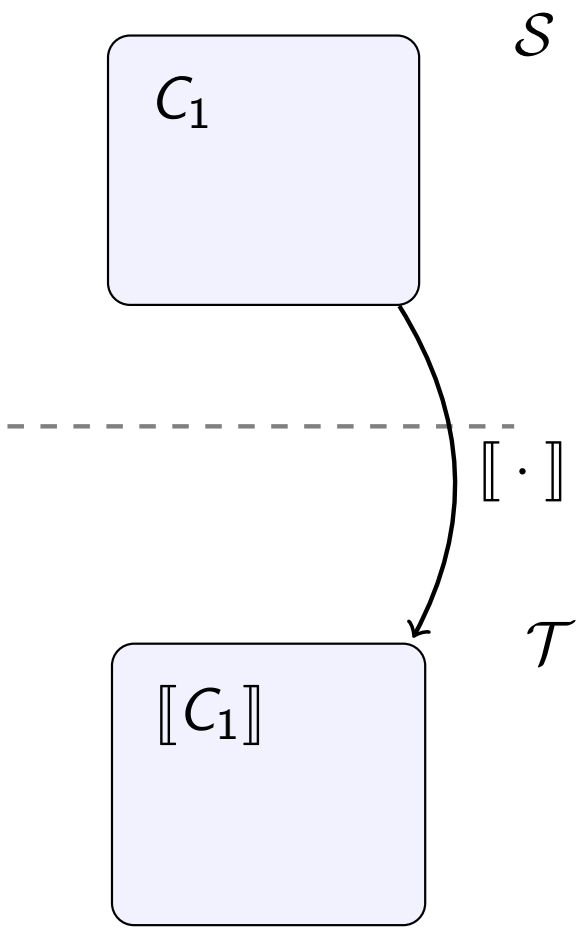

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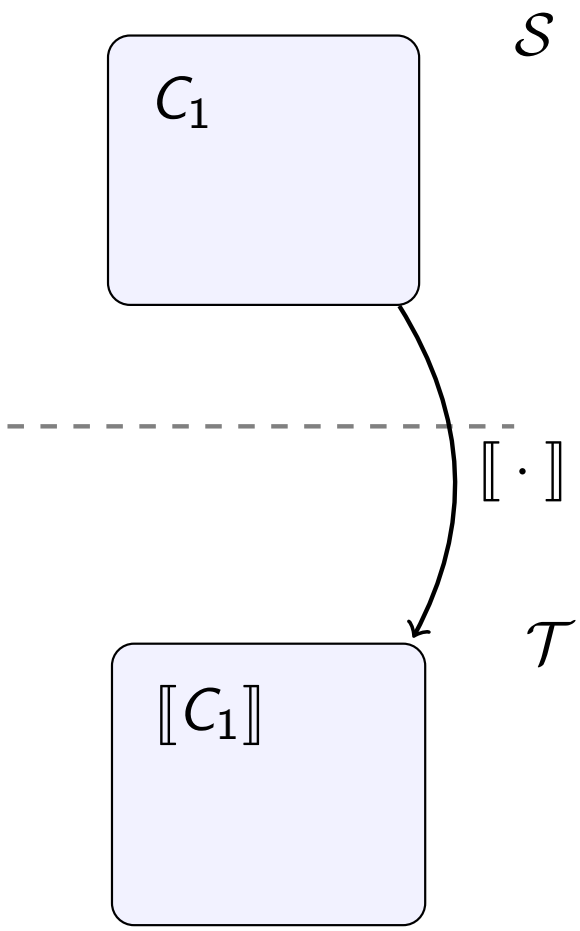

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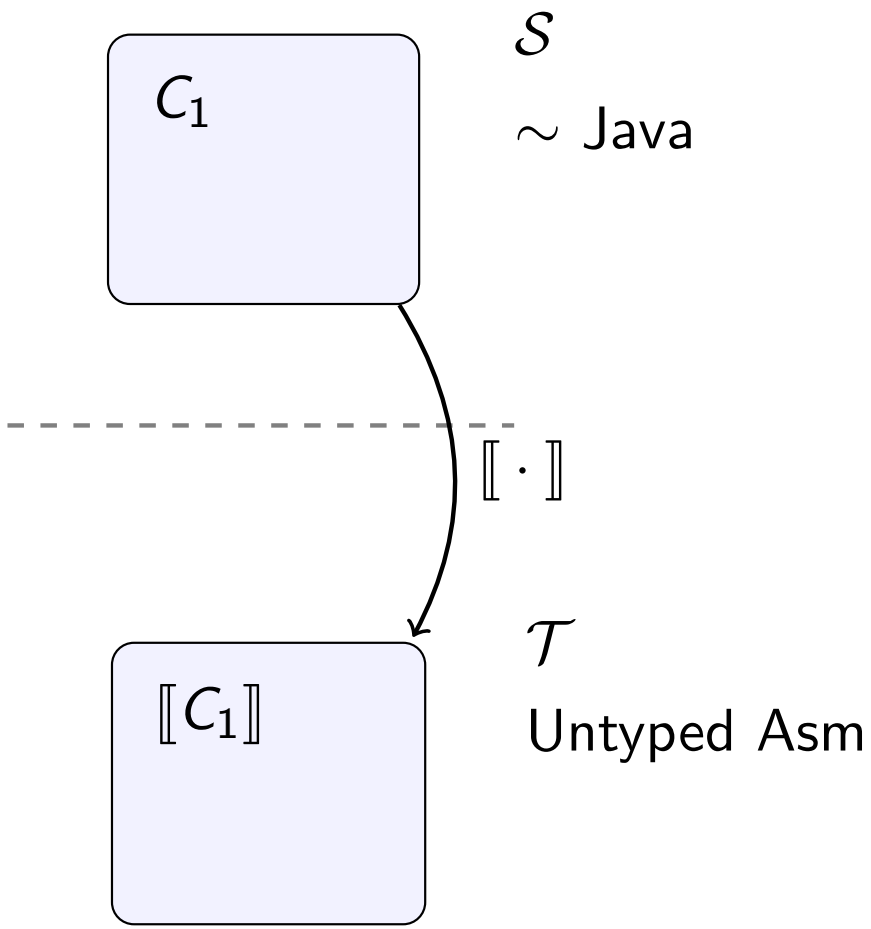

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- protect against code injection attacks
- enable source-level reasoning

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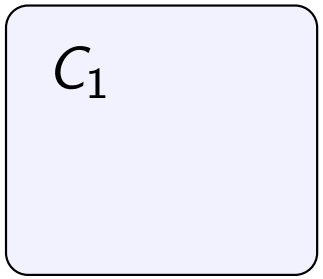
- $\simeq$ implies security properties e.g., confidentiality, integrity, etc

Outline

Compiler INsecurity



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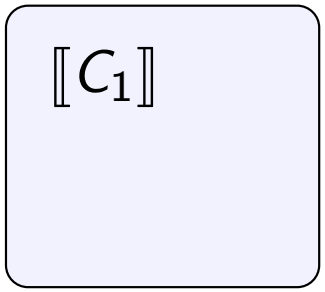

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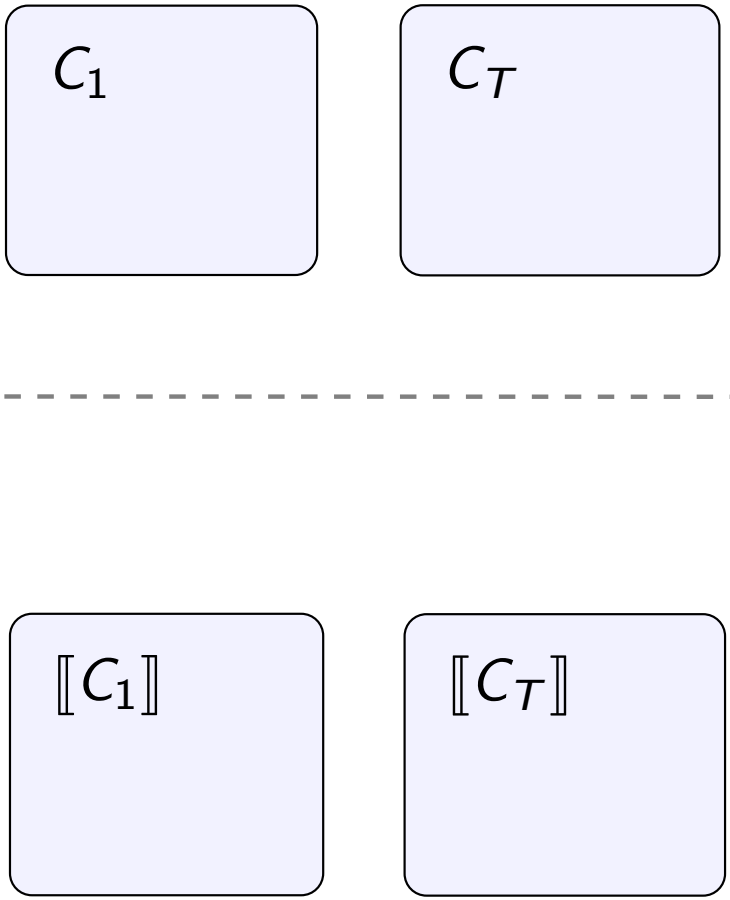

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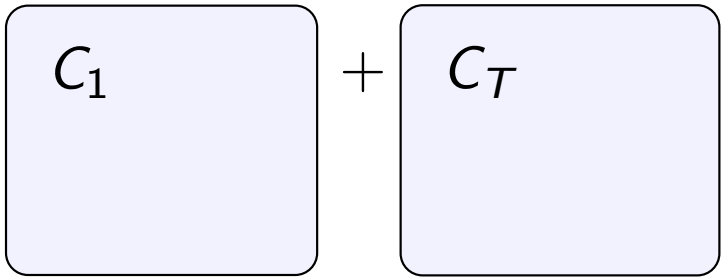

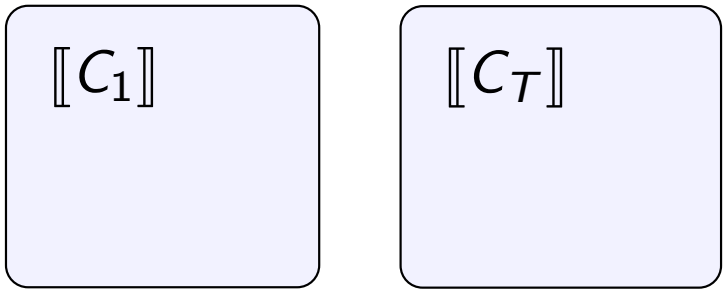

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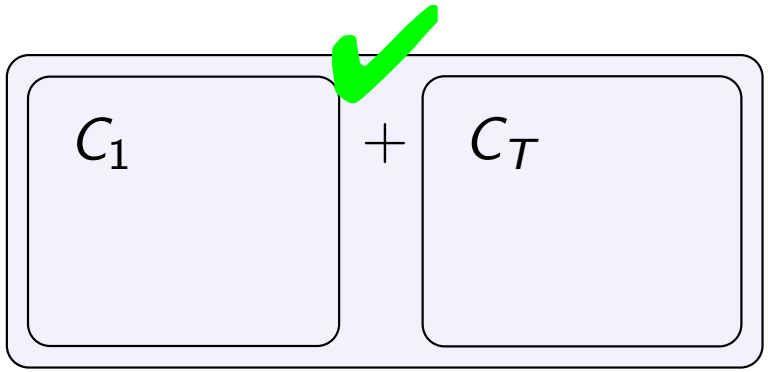

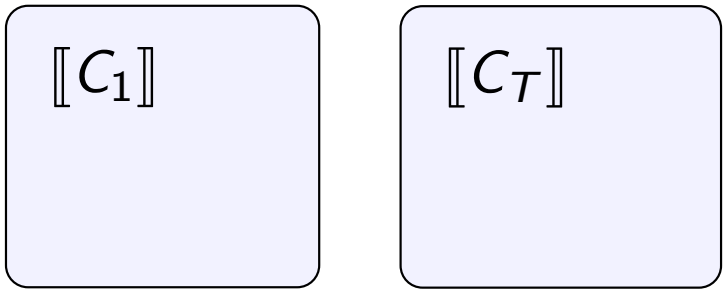

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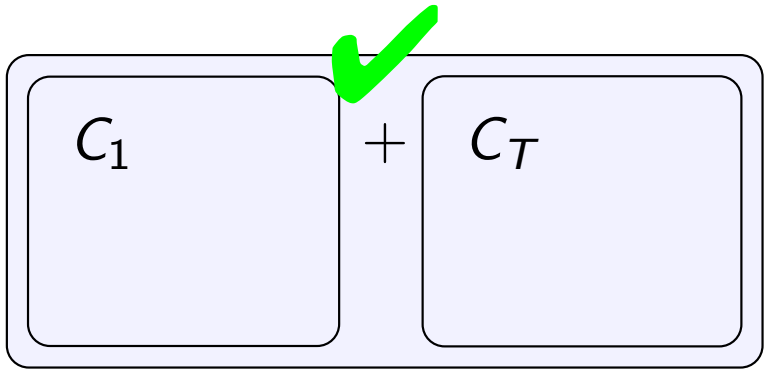

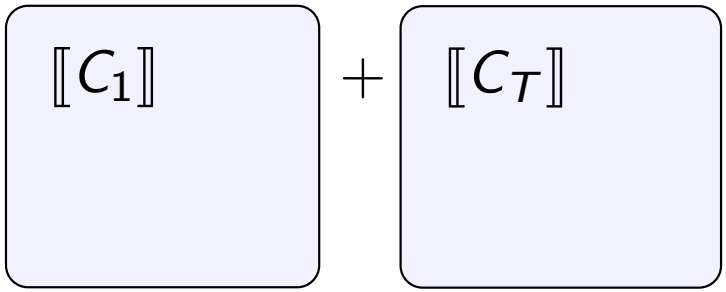

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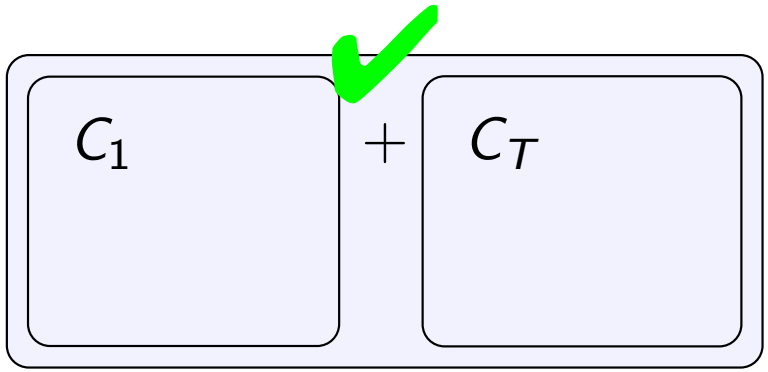

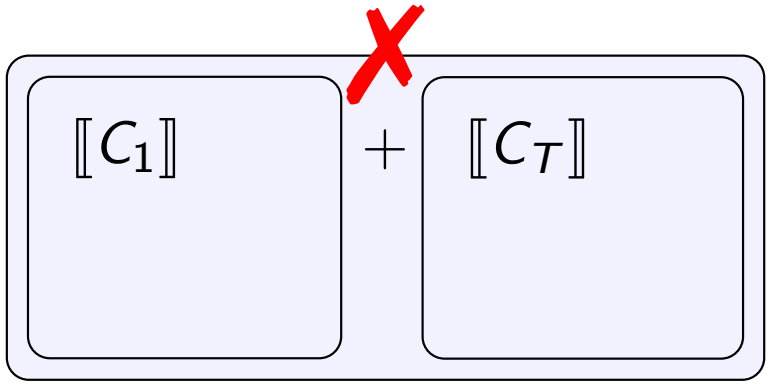

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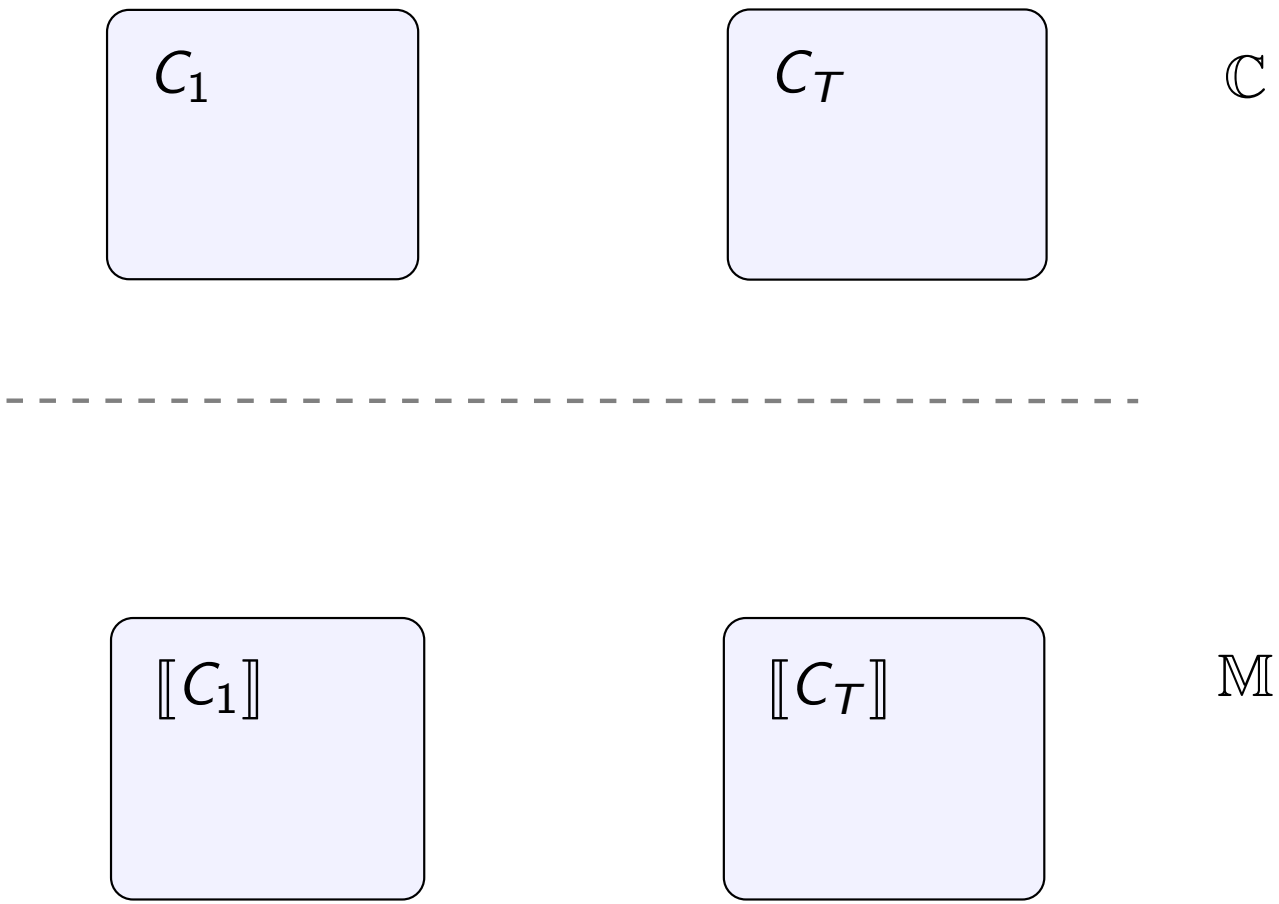

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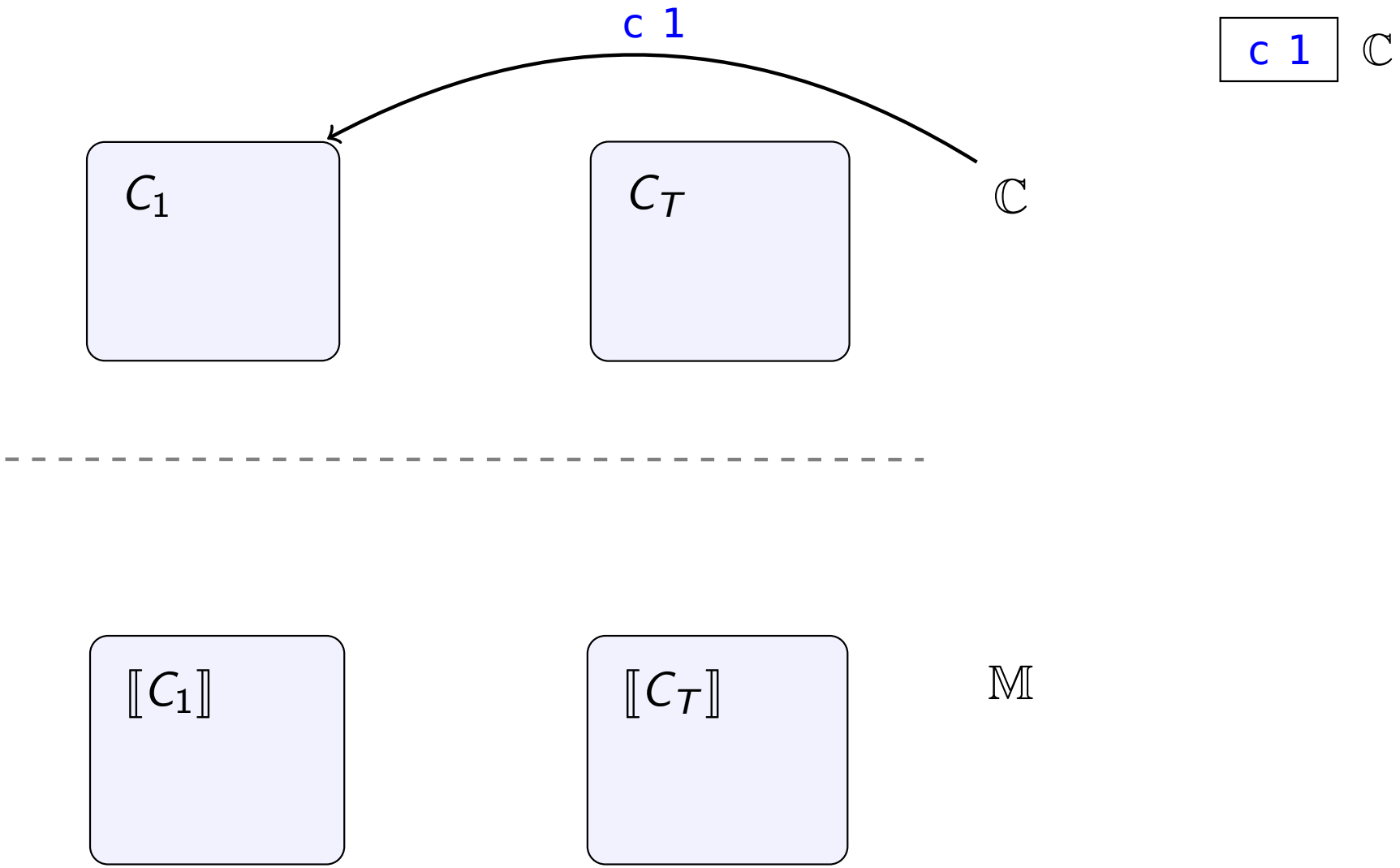

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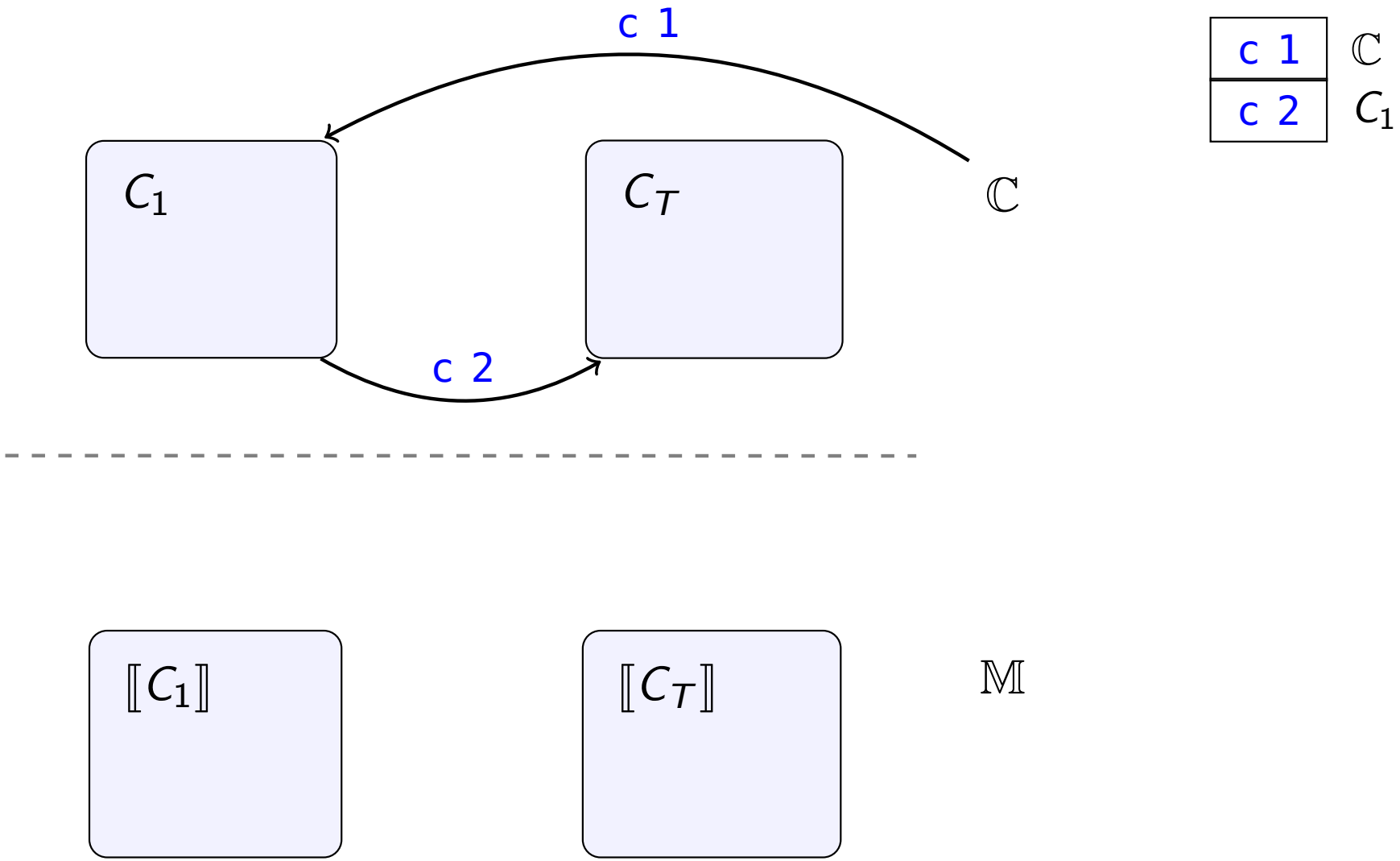

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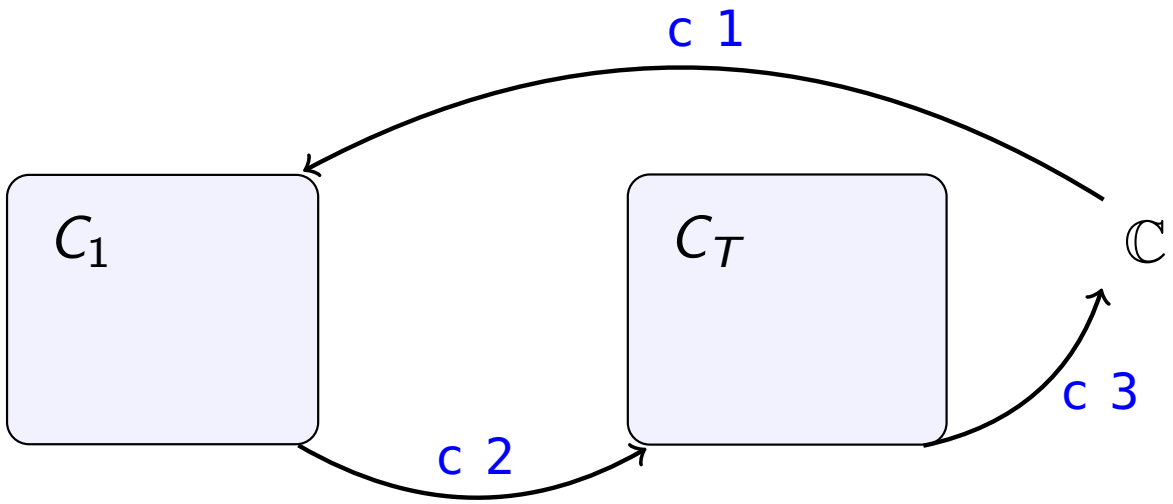

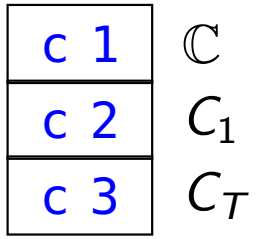

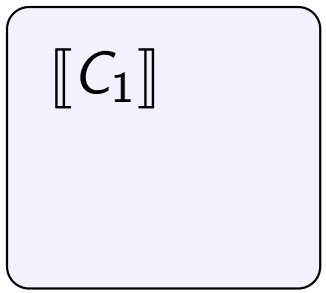

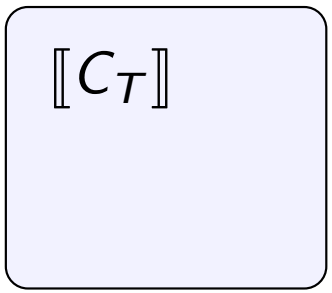

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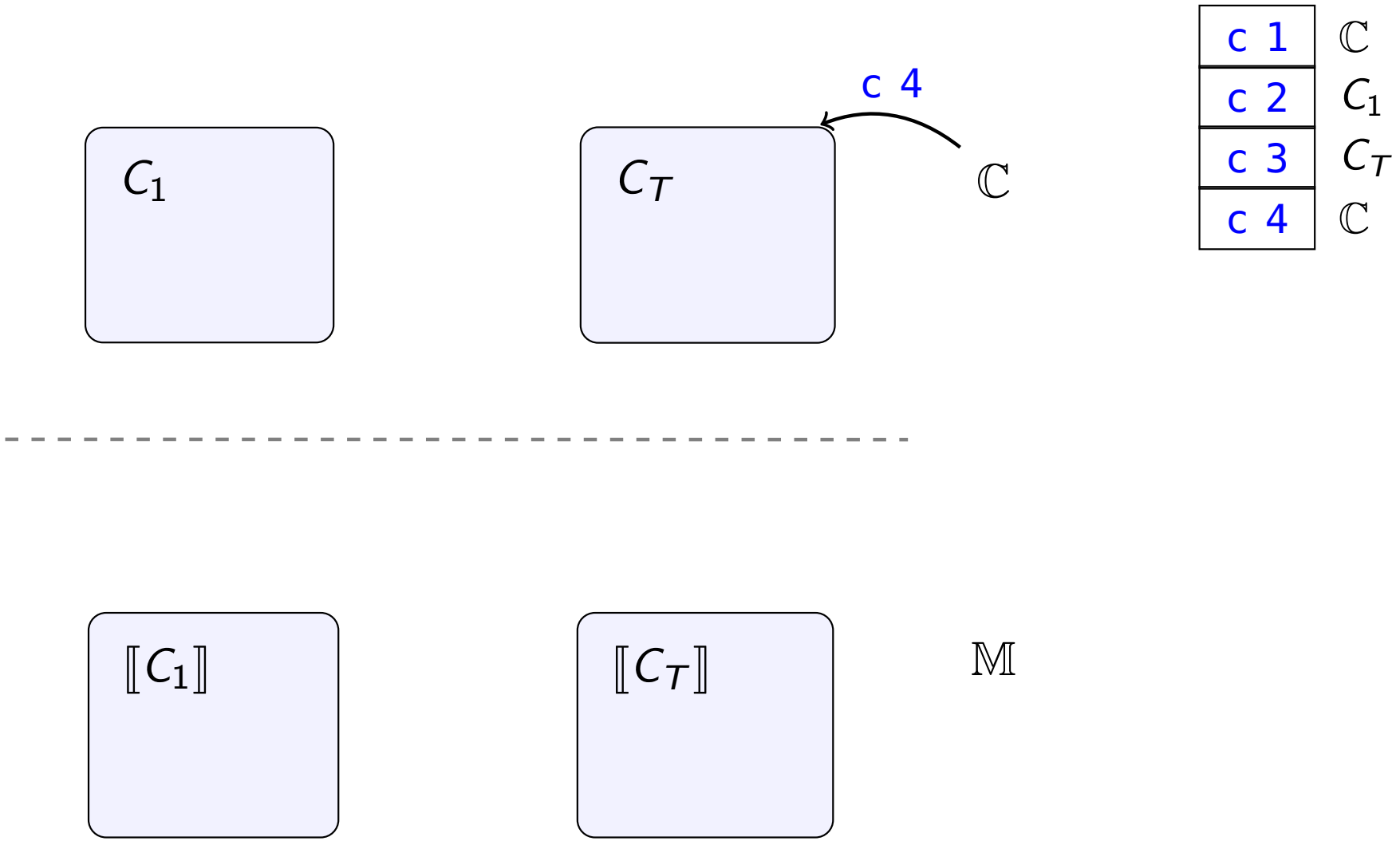

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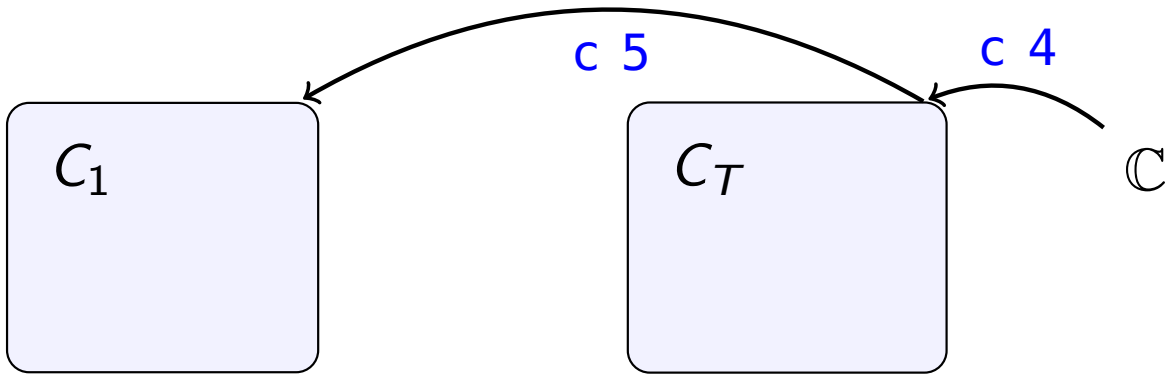

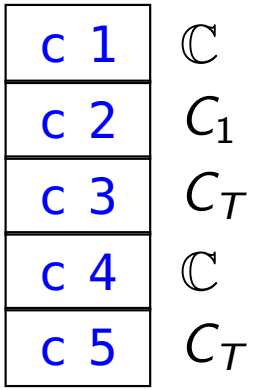

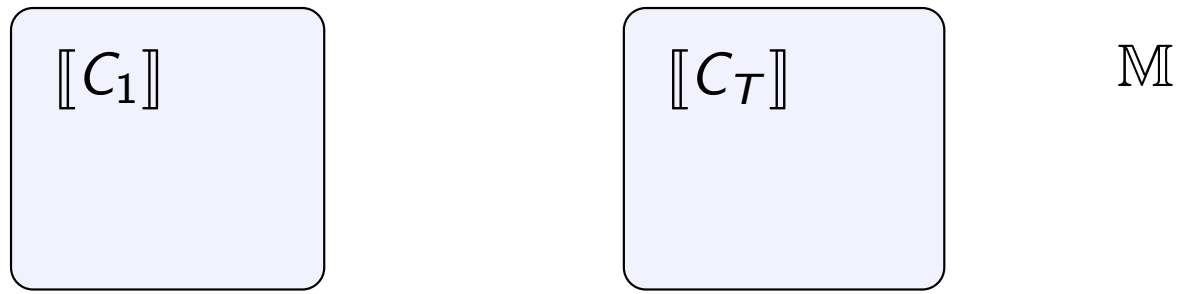

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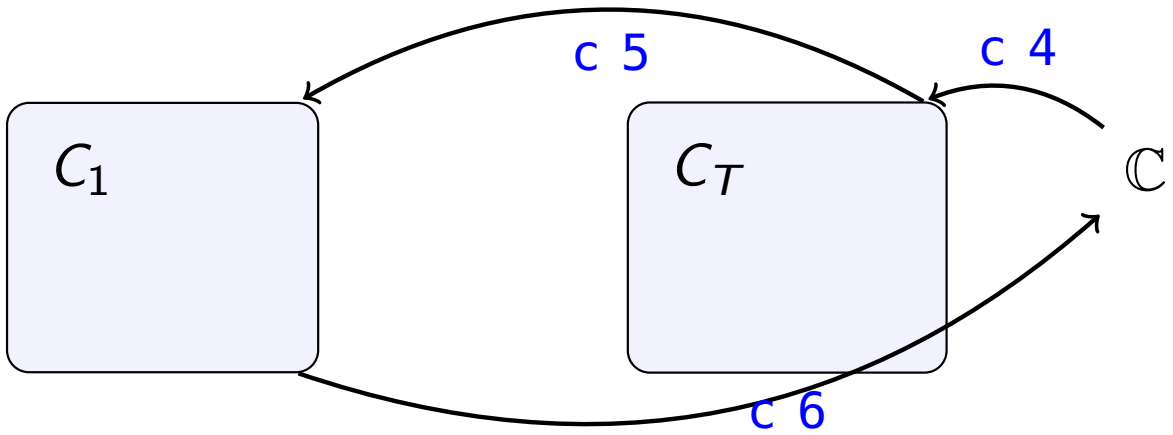

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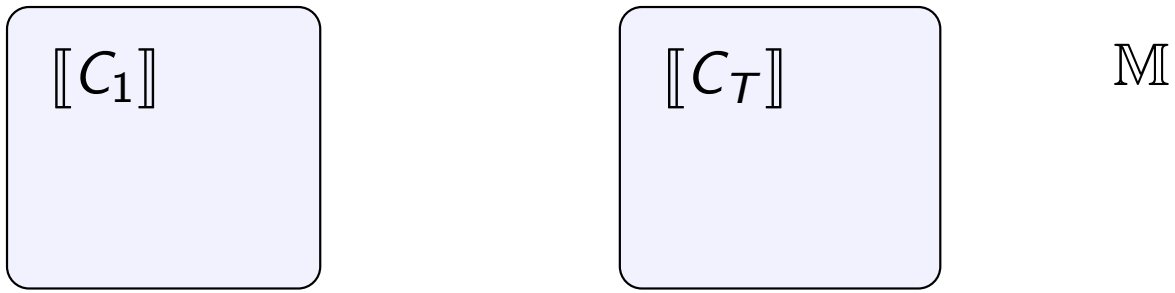

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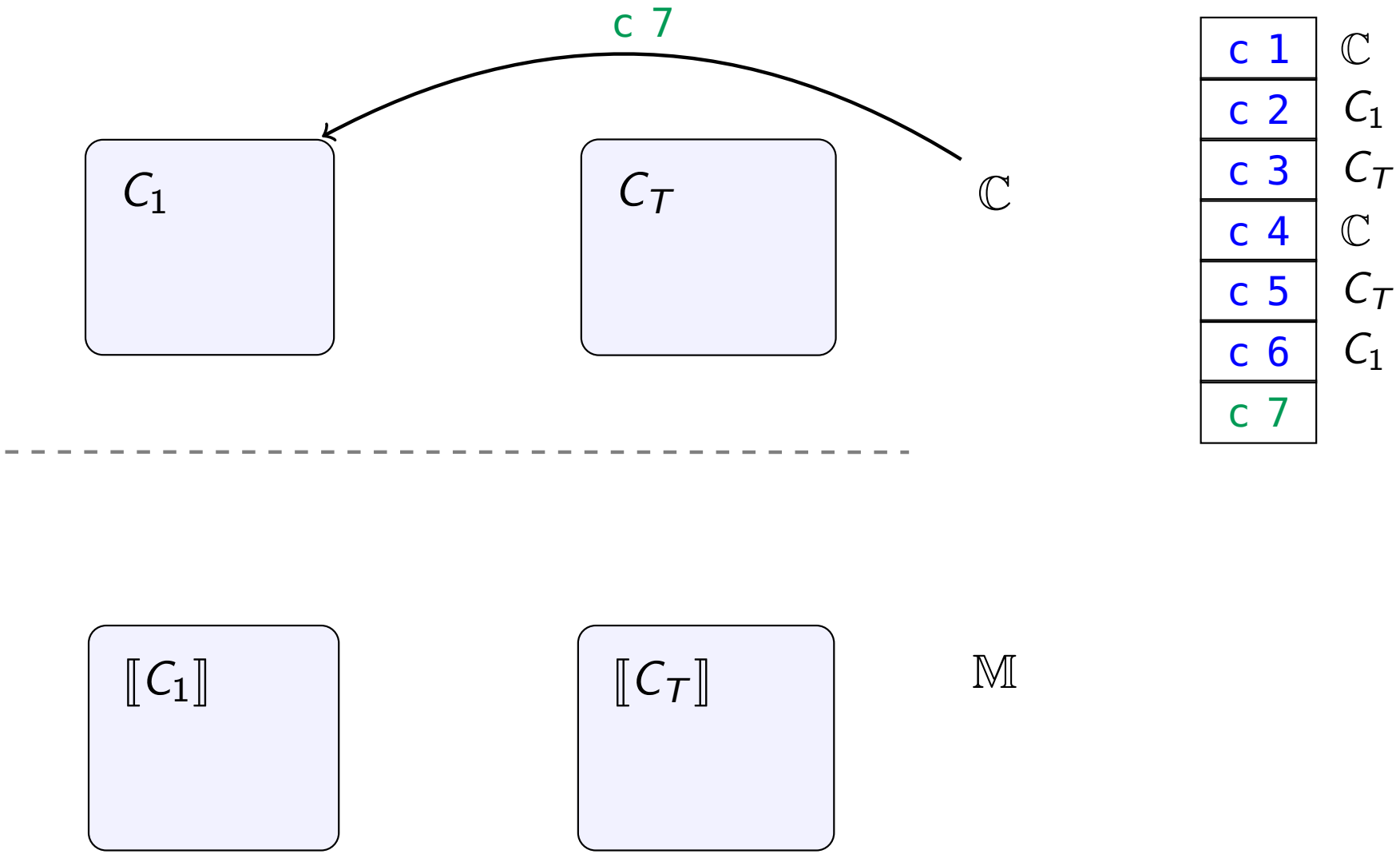

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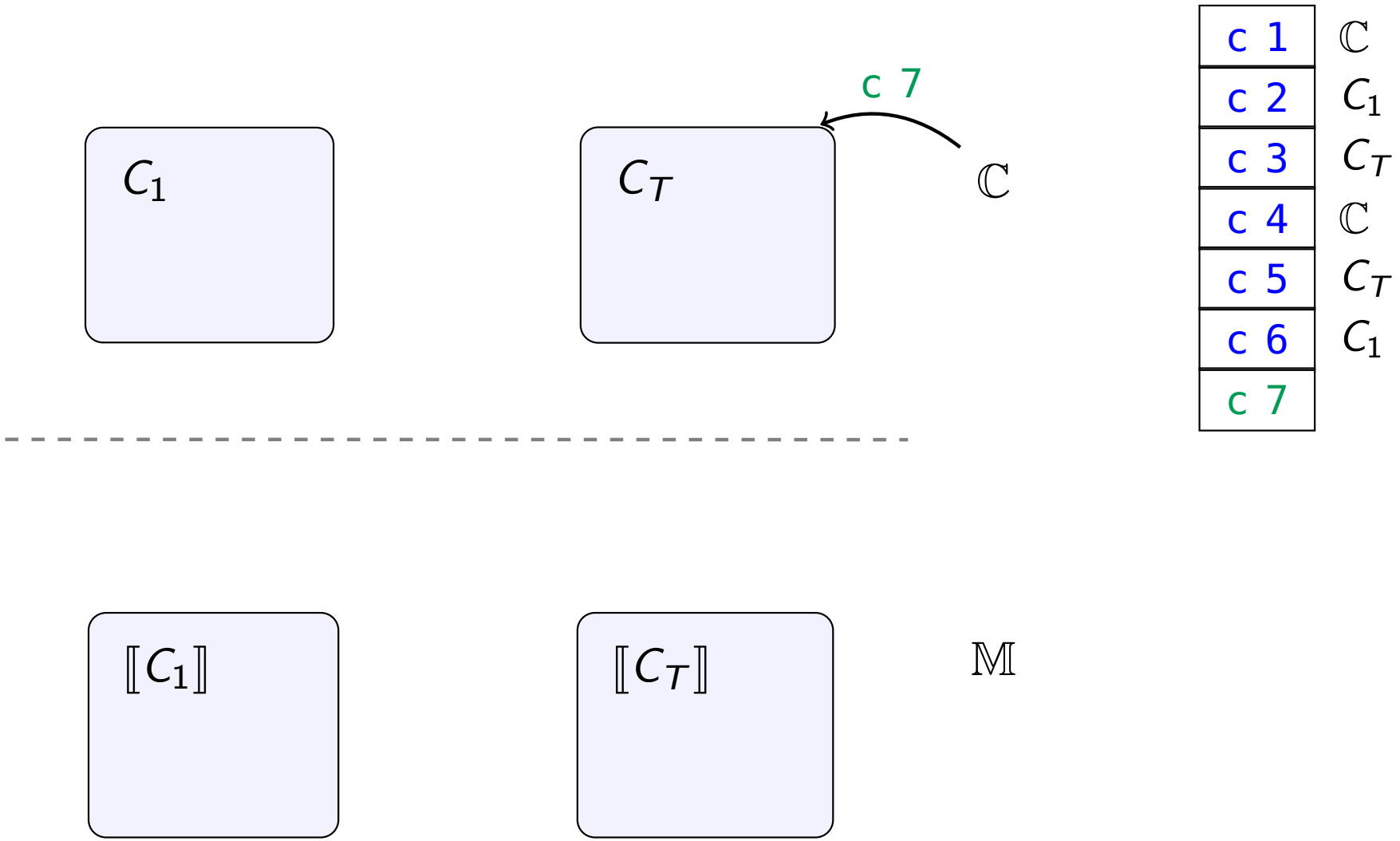

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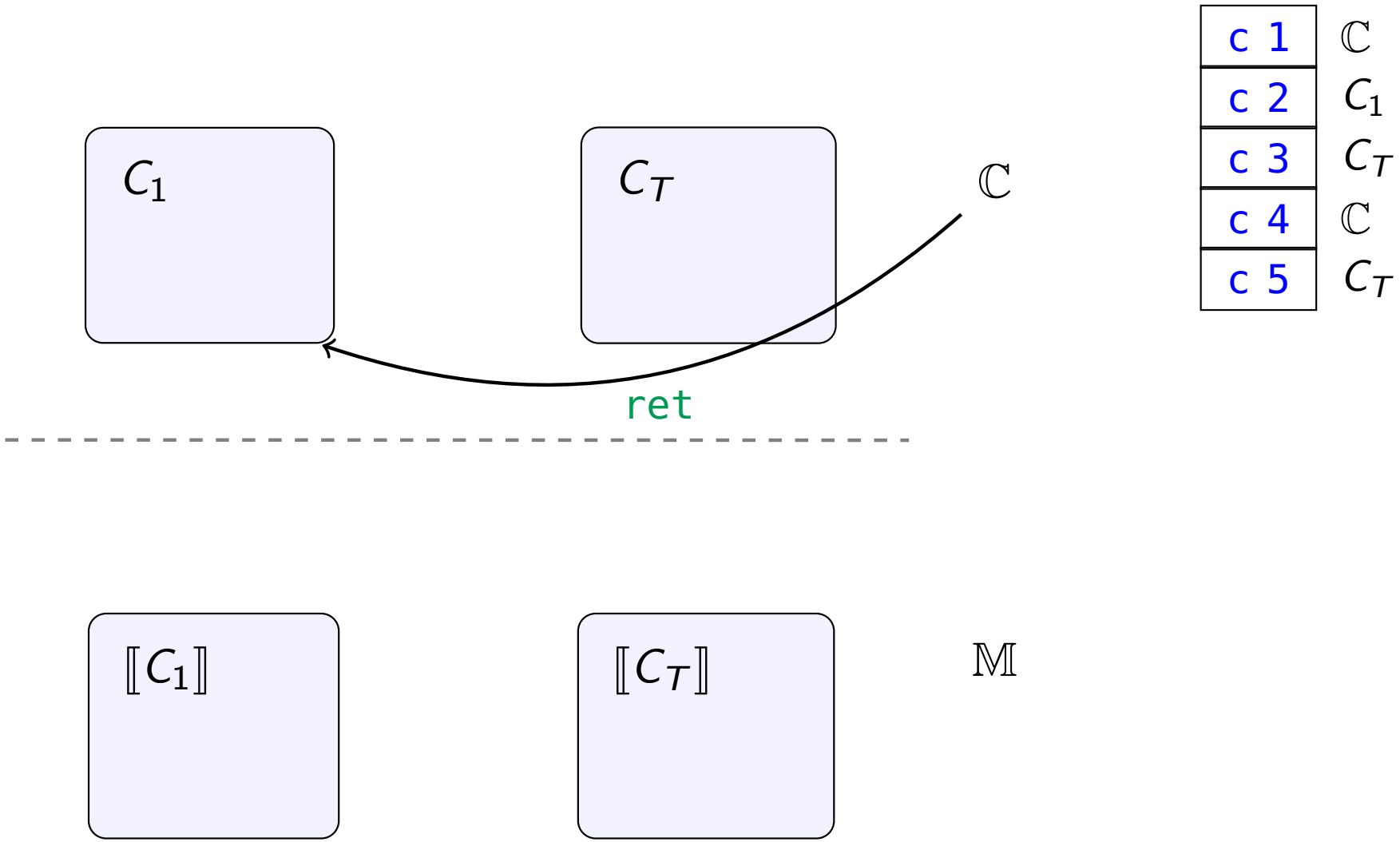

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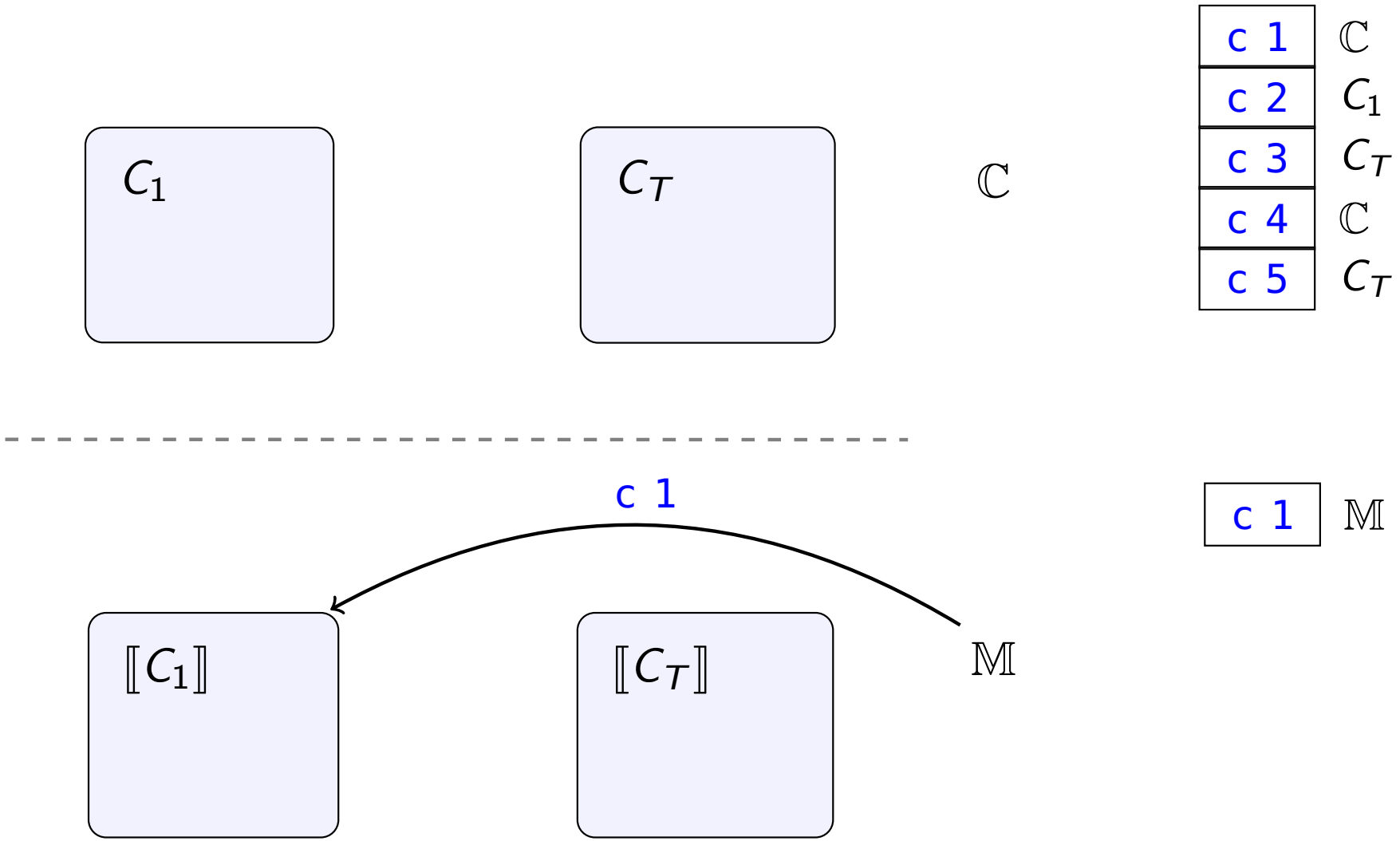

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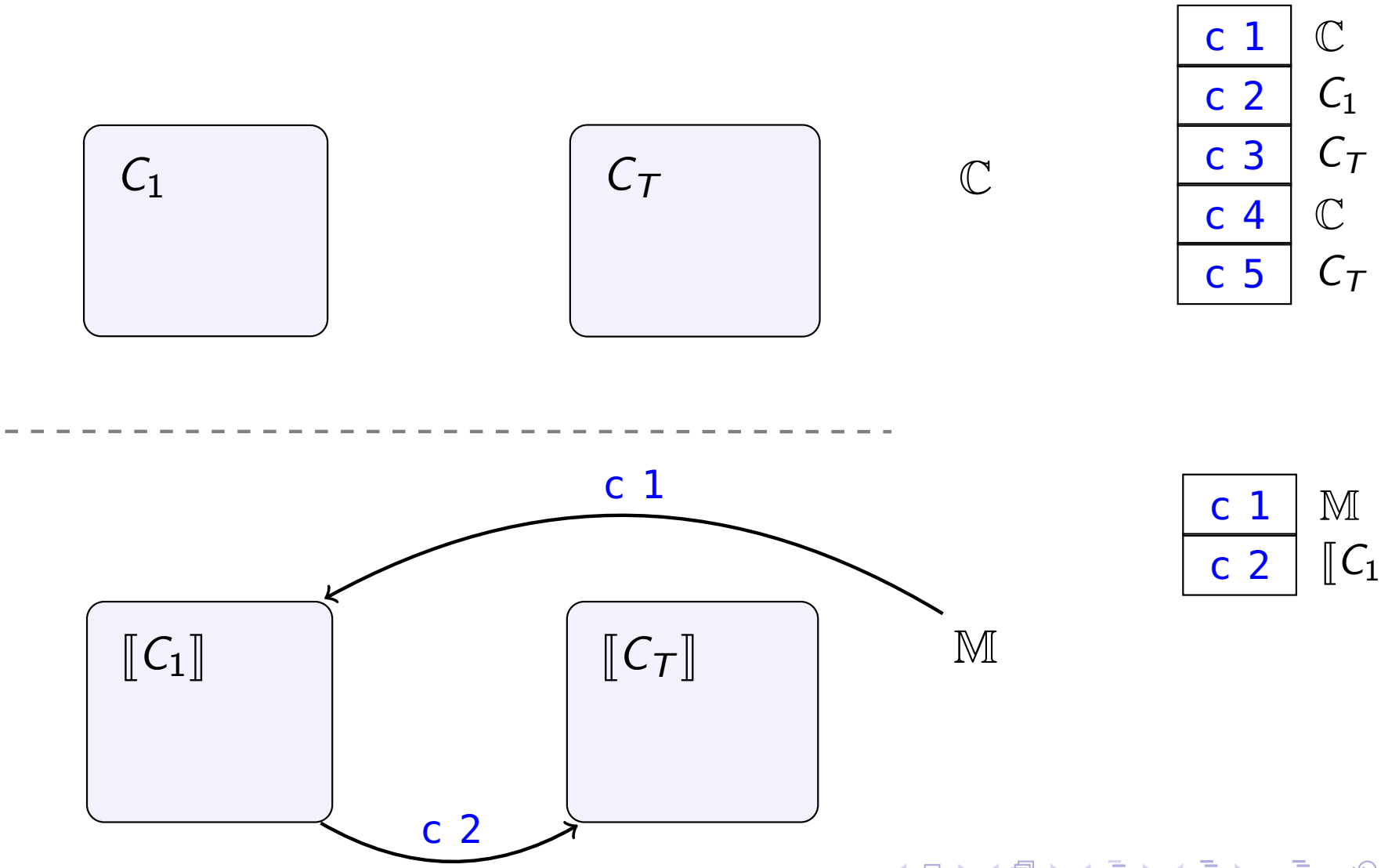

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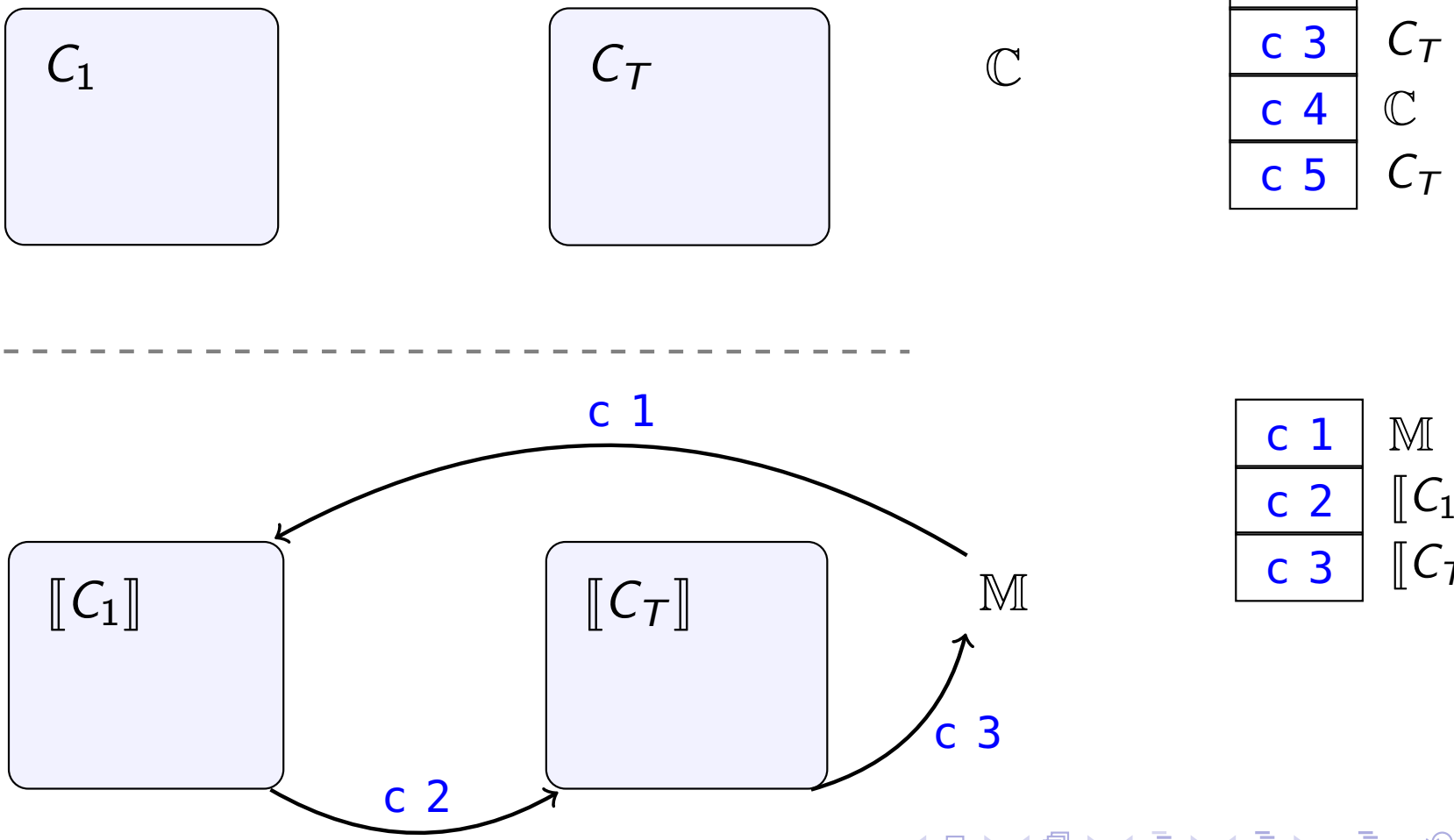

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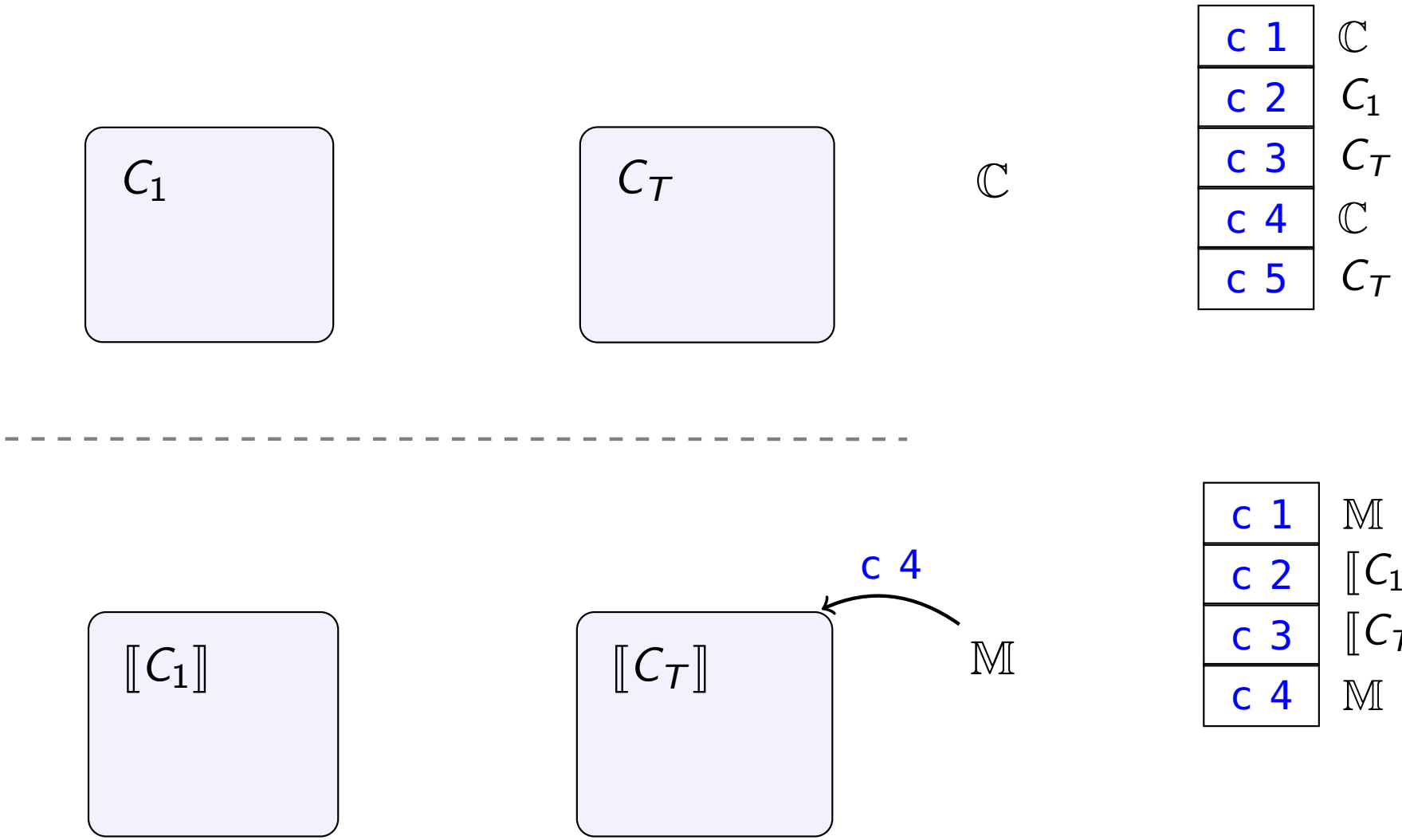

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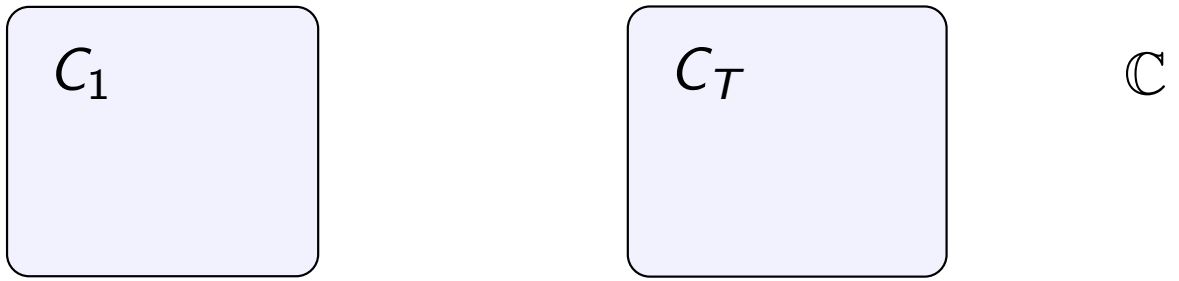

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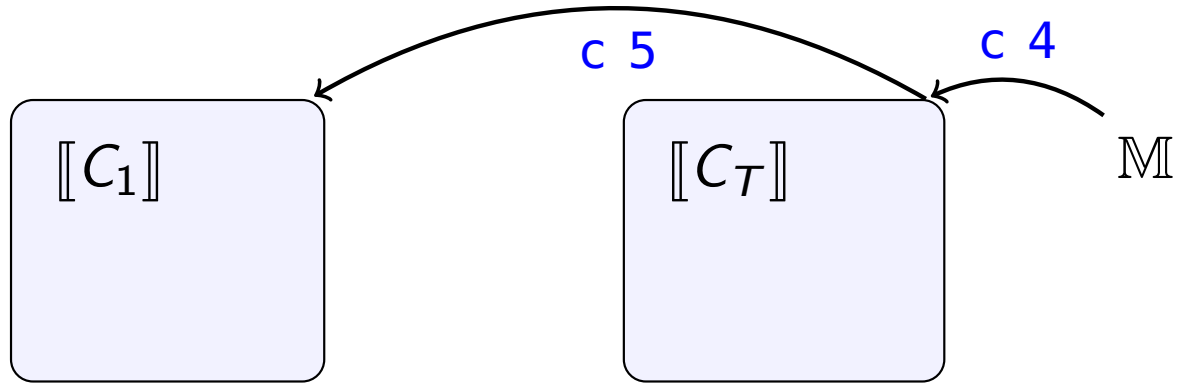

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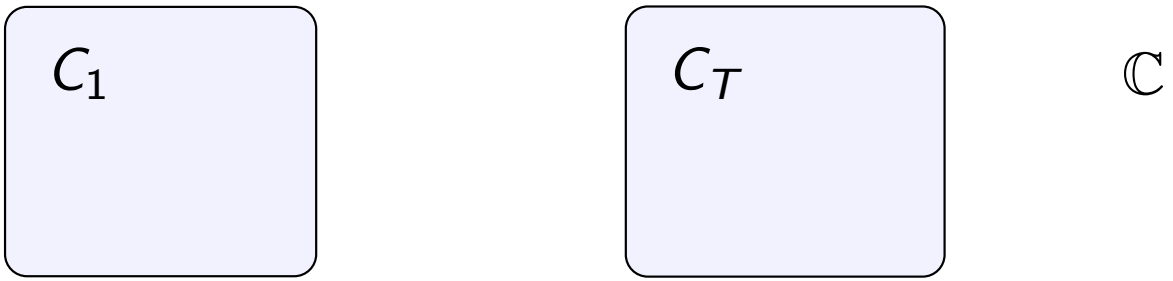

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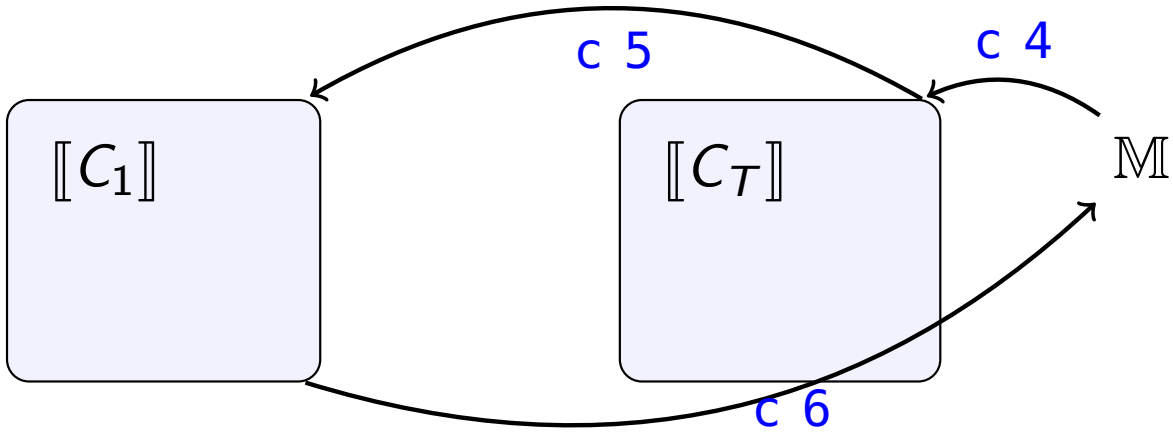

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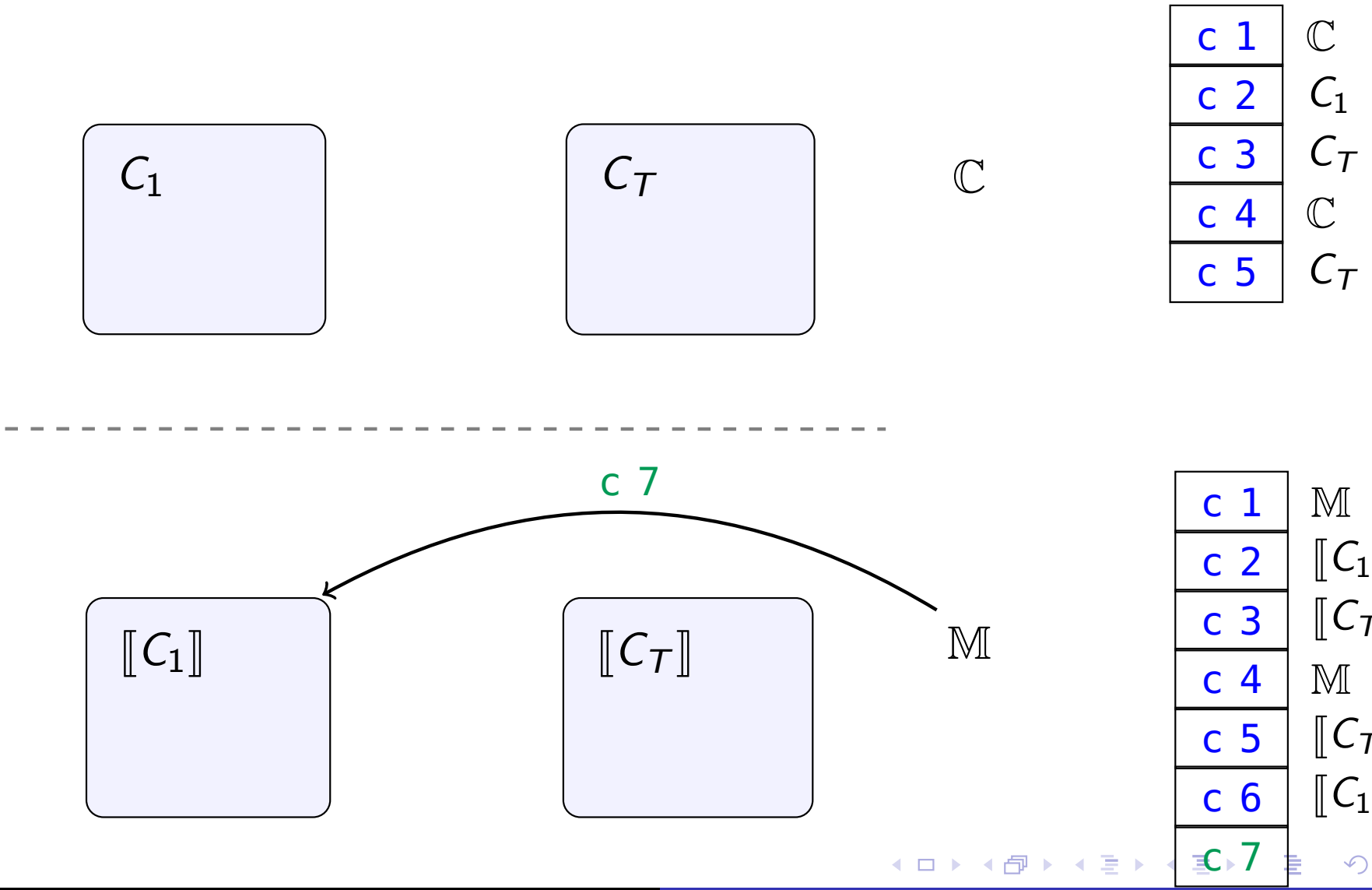

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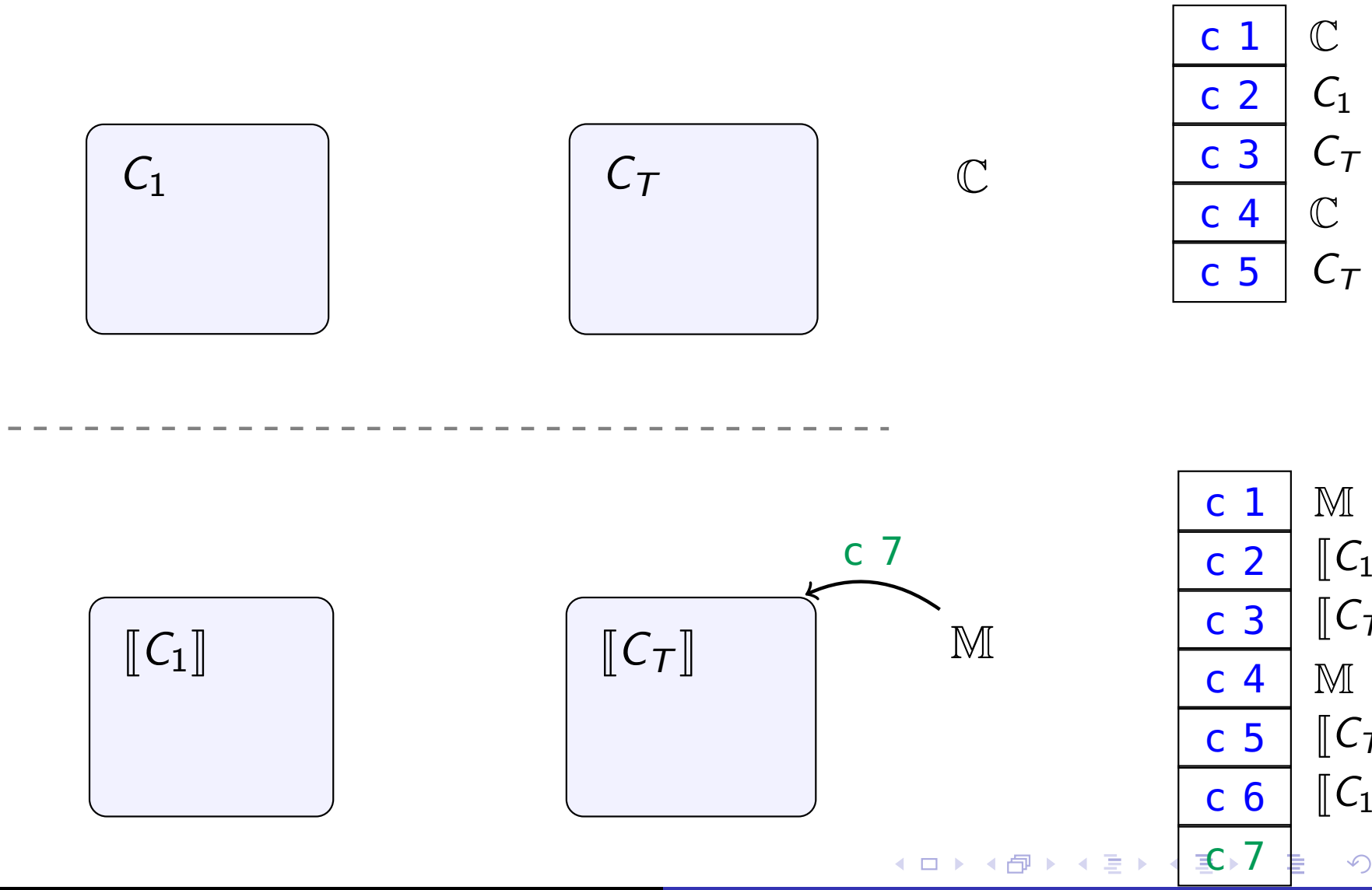

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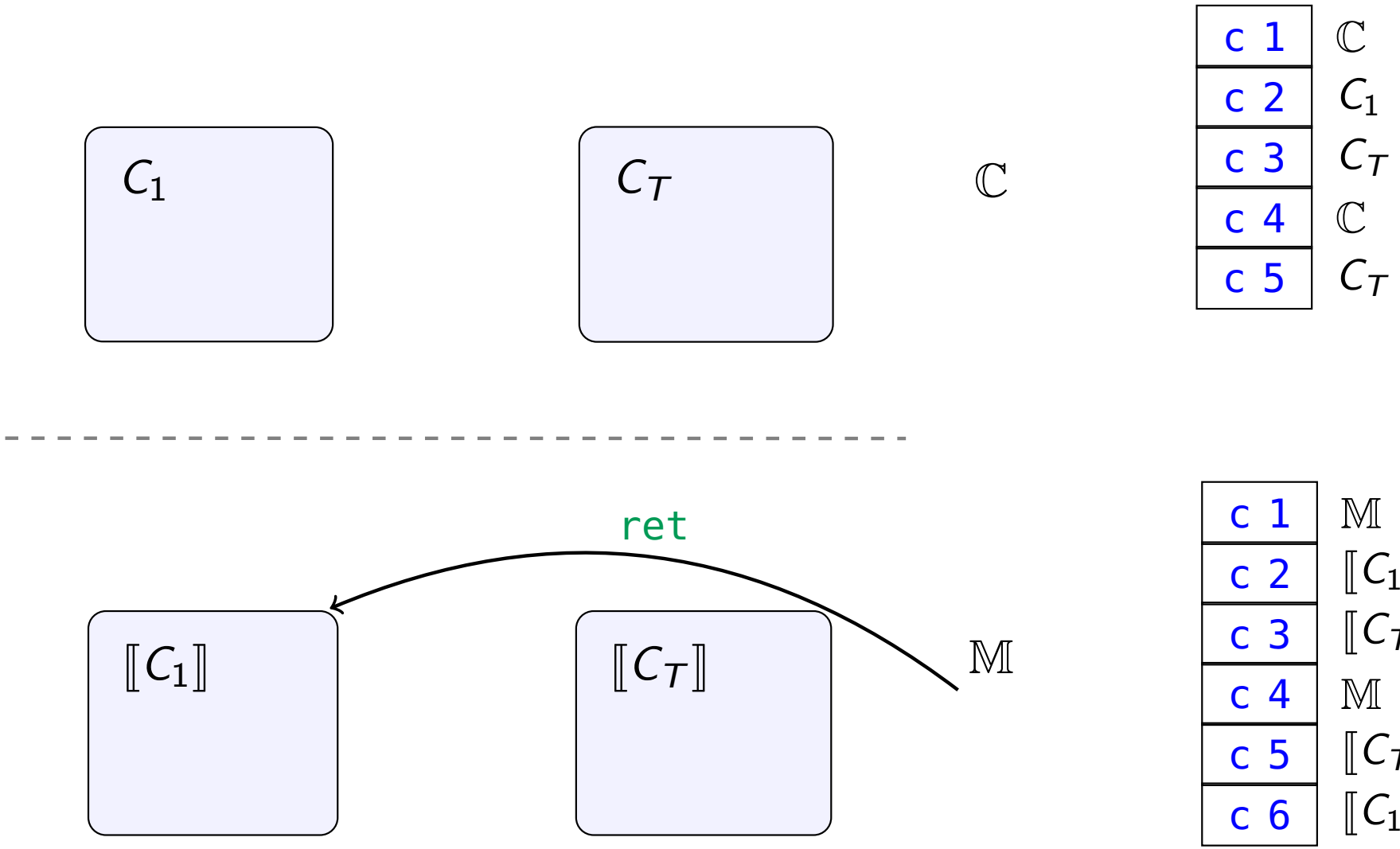

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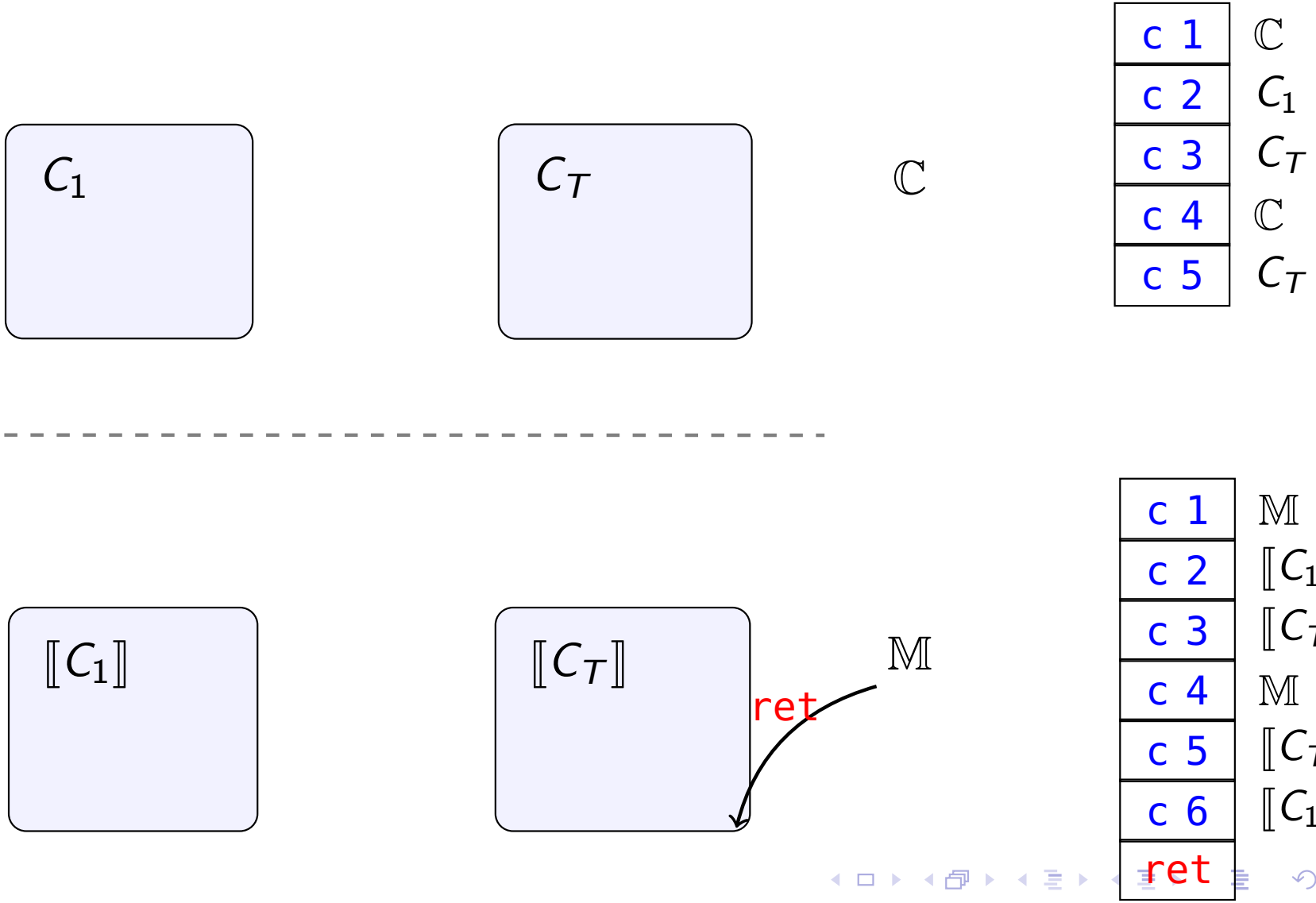
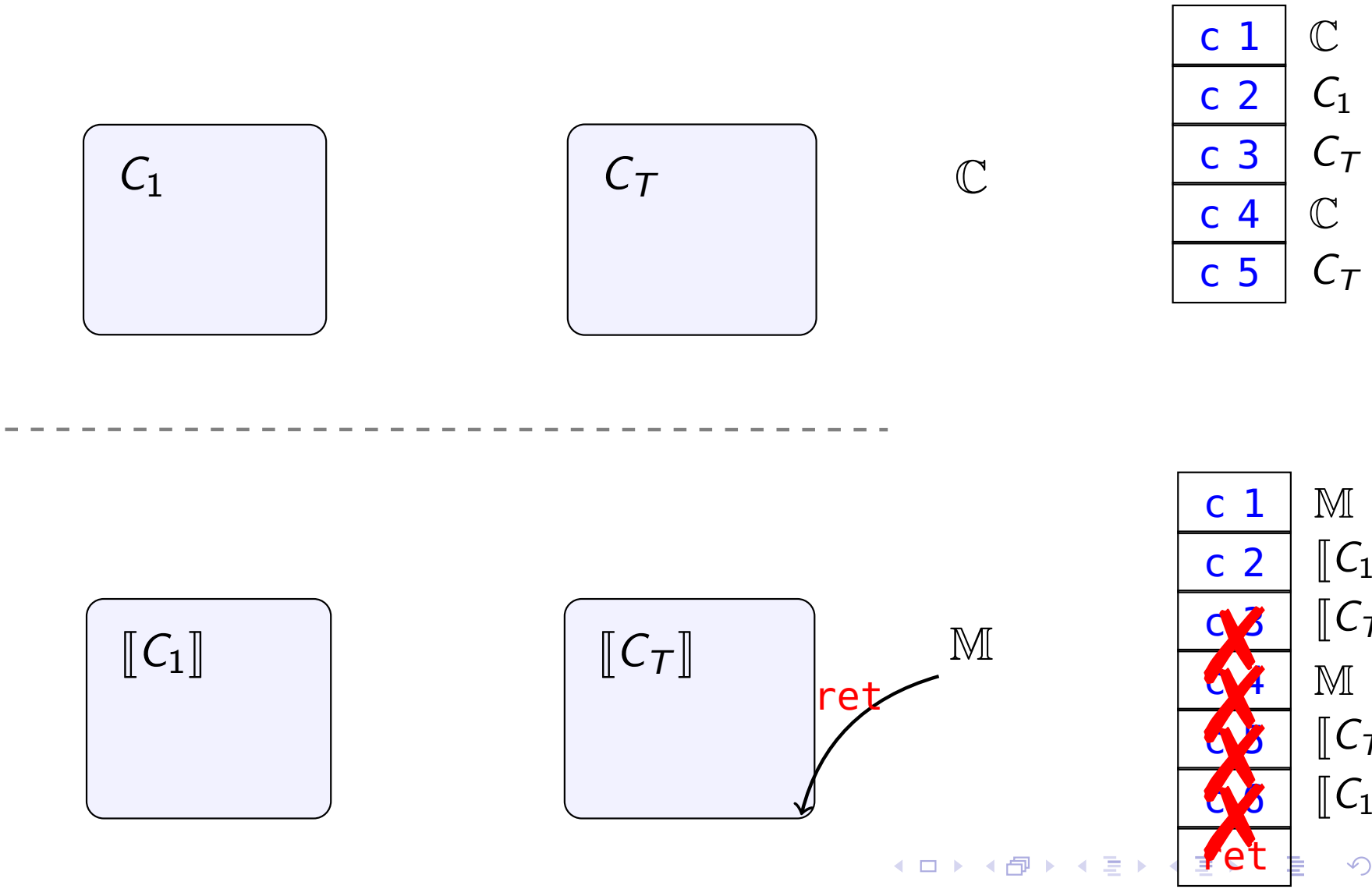
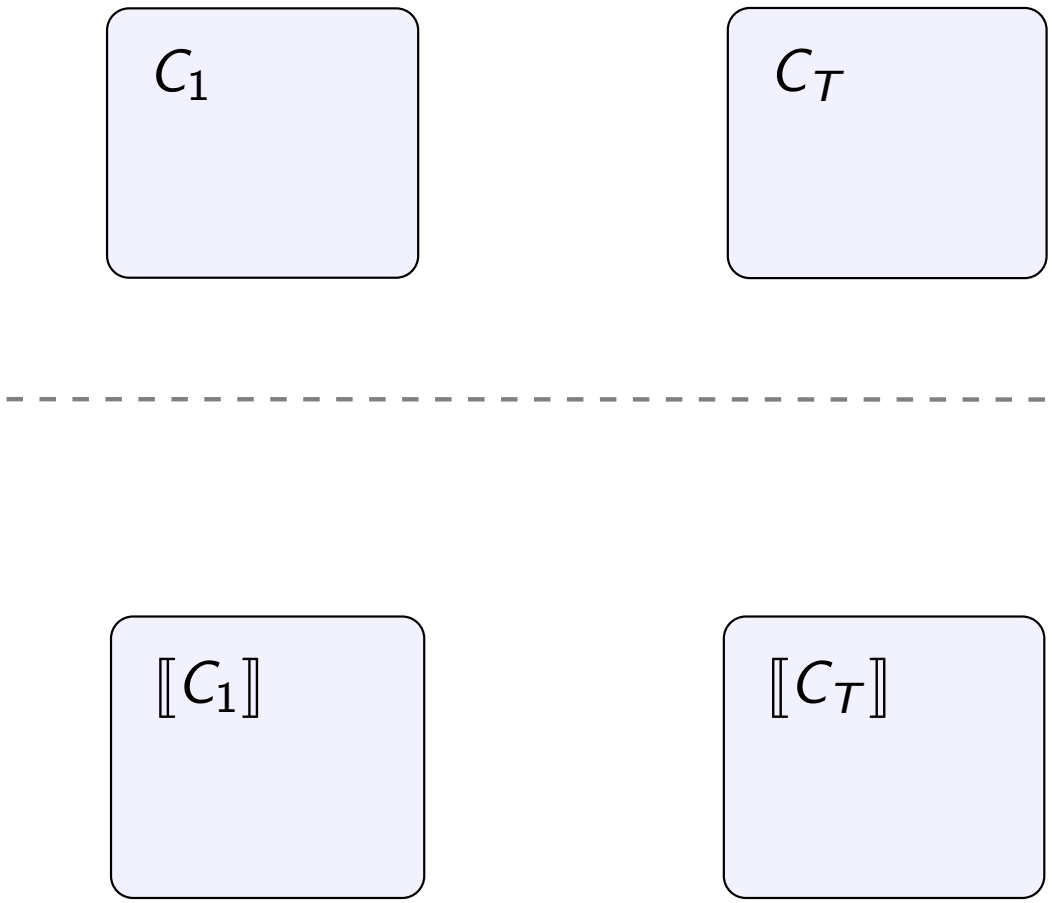


Call Stack Shortcutting



Object Guessing



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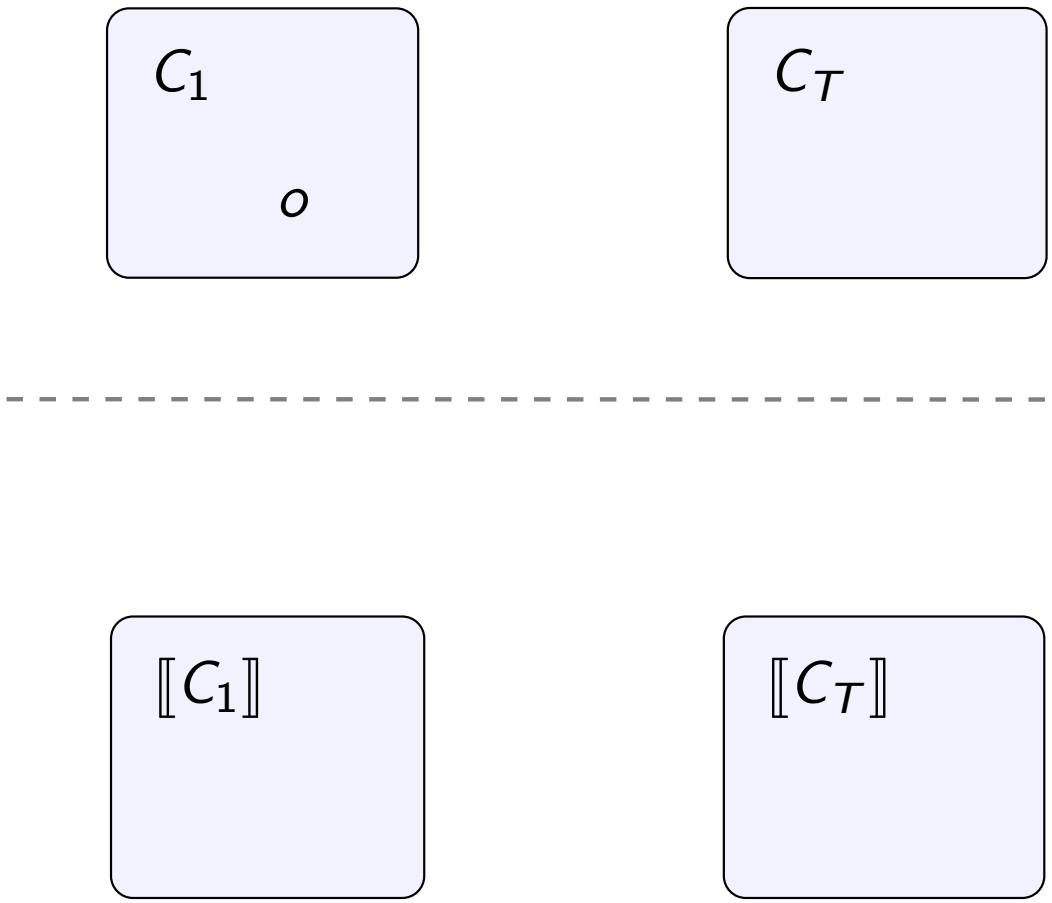
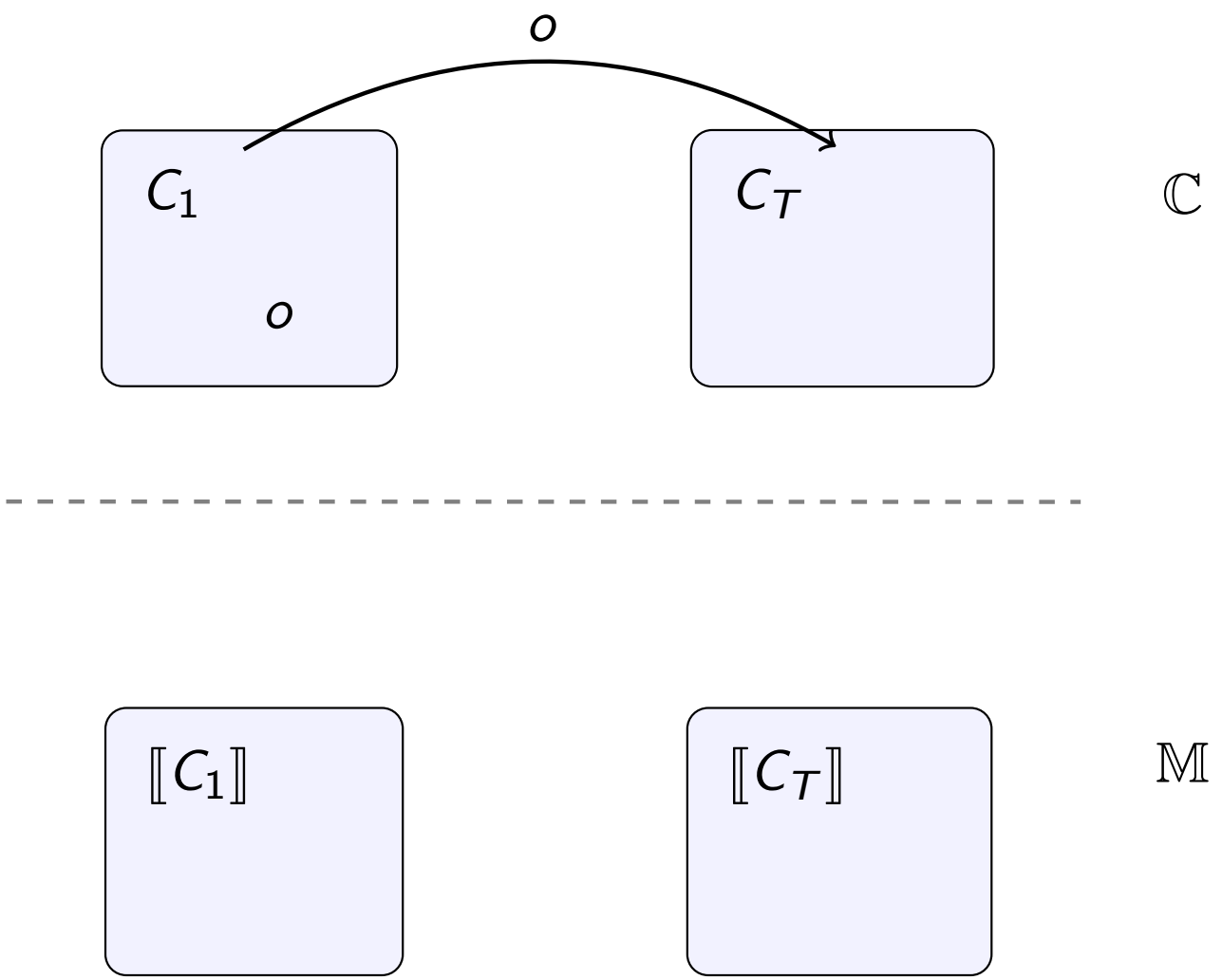
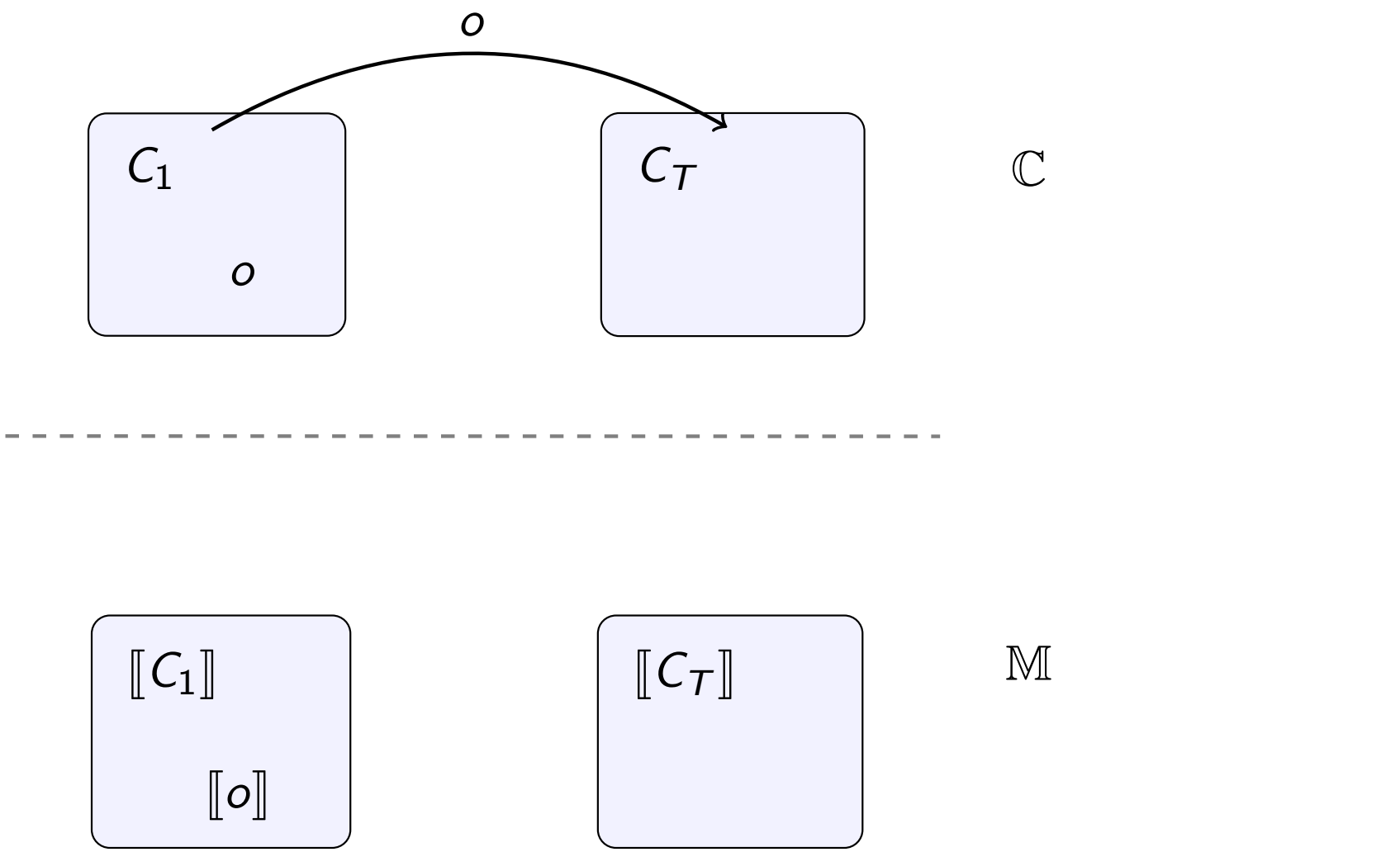


Object Guessing



Object Guessing



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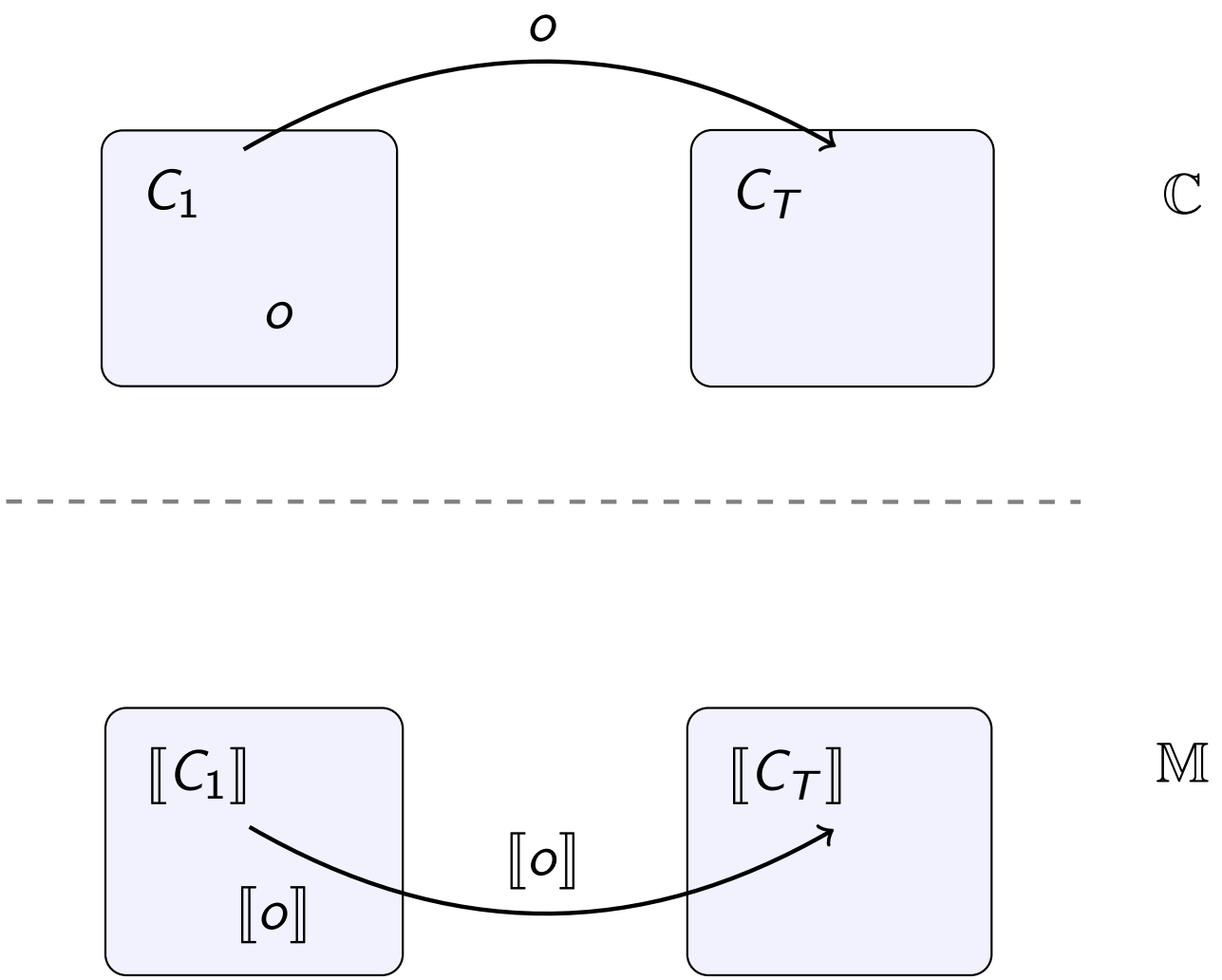
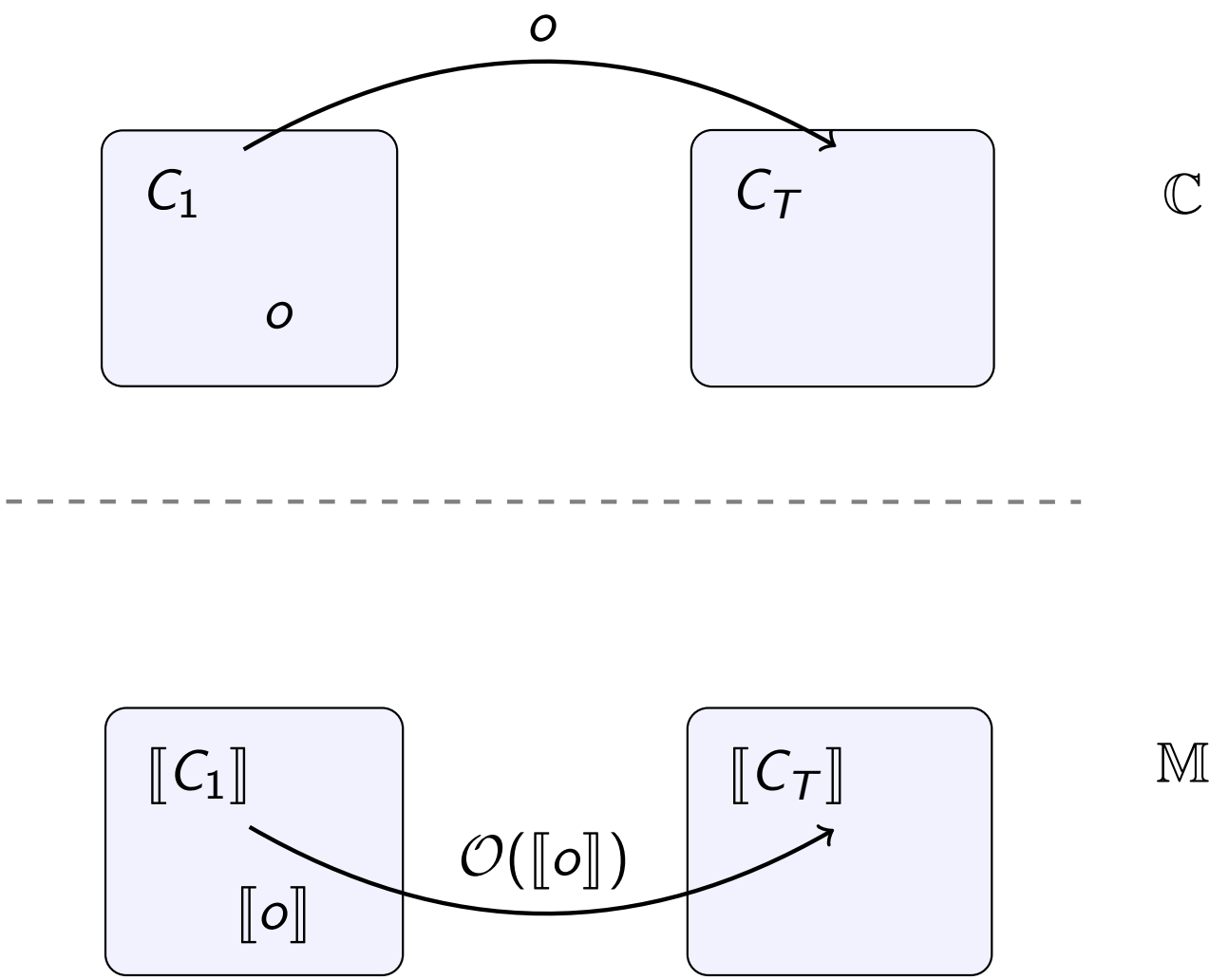
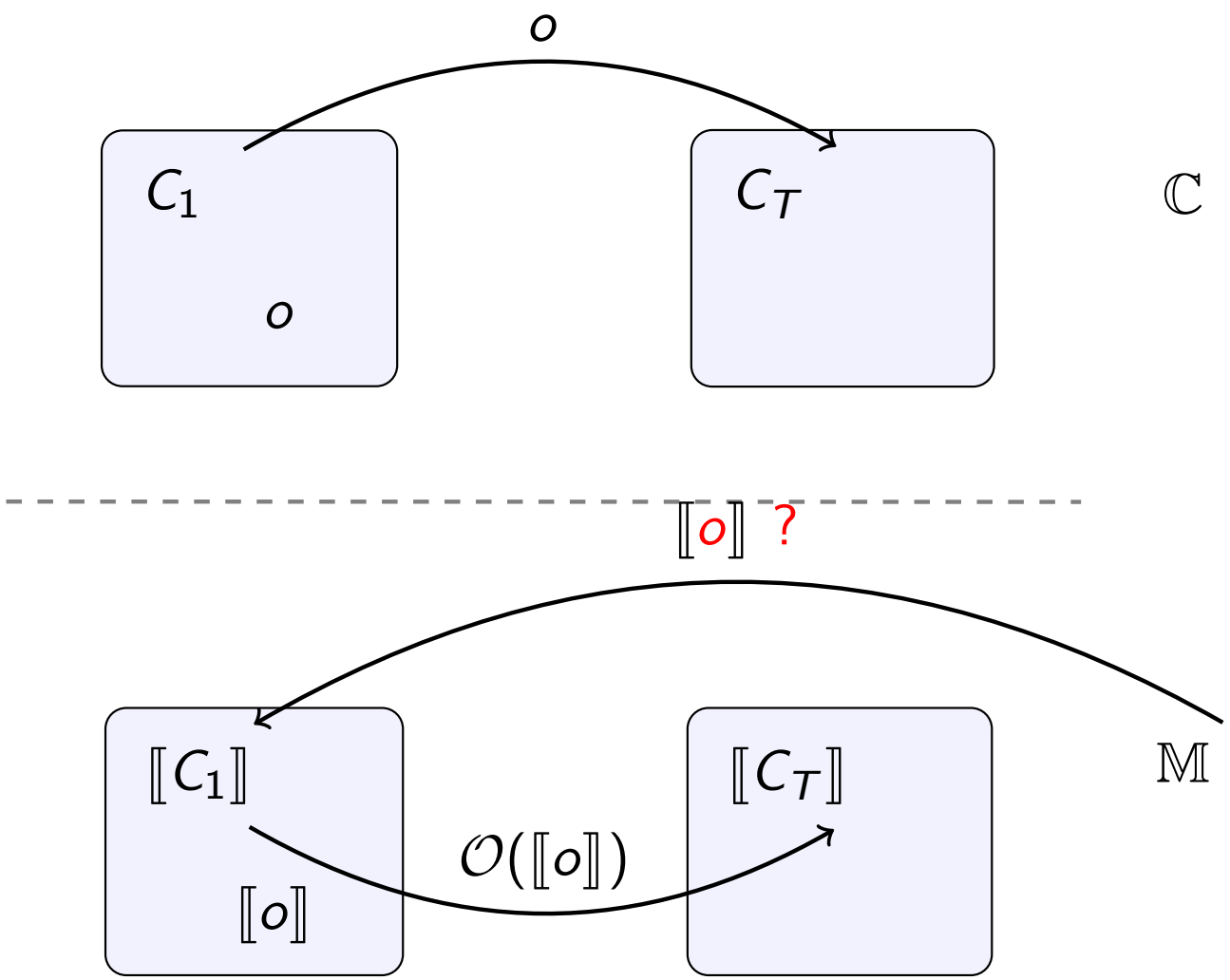


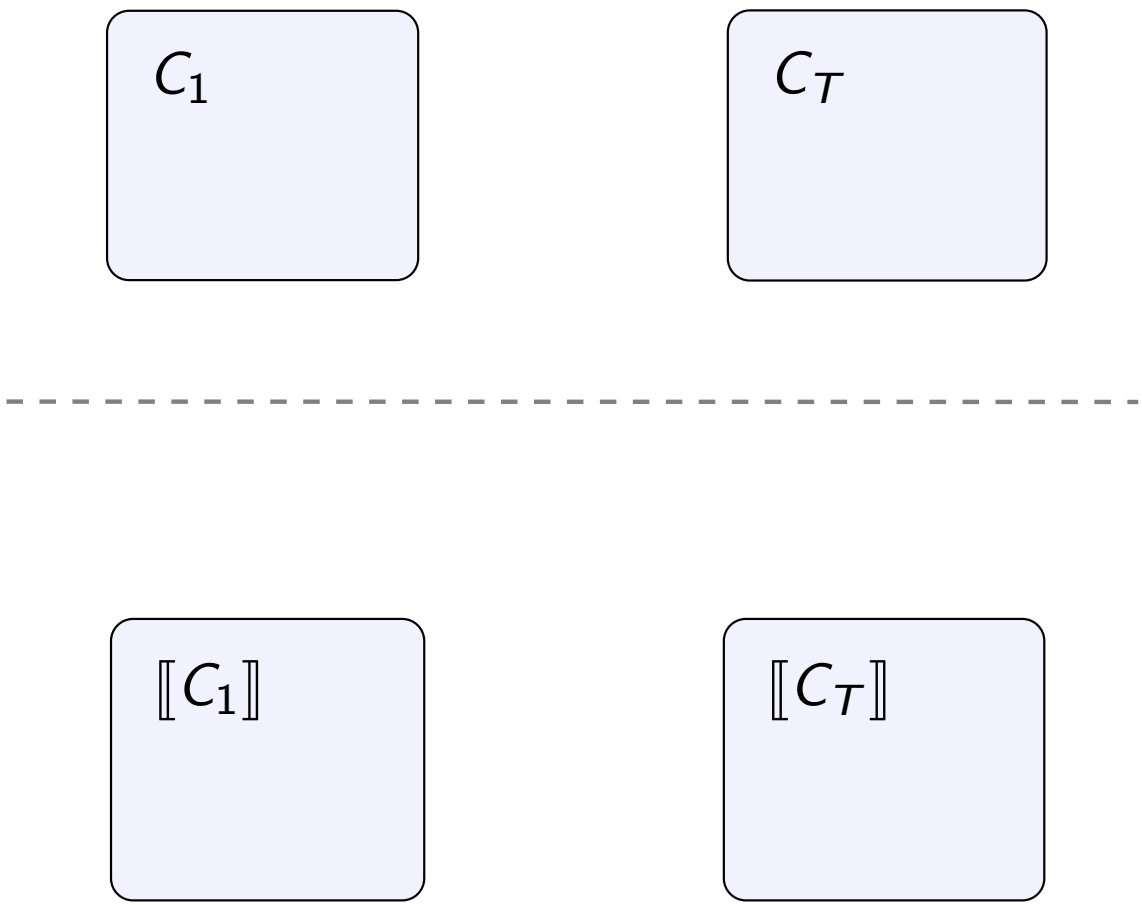
Object Guessing



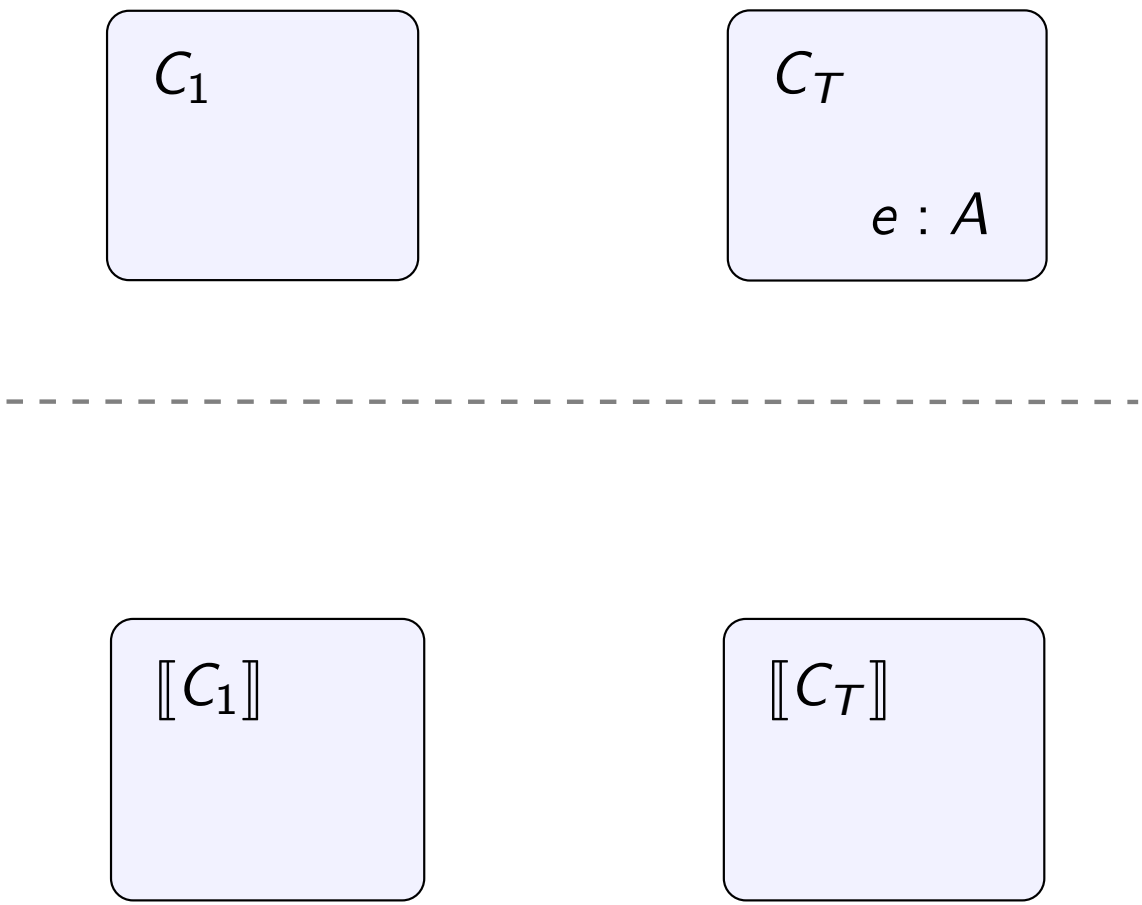
Object Guessing



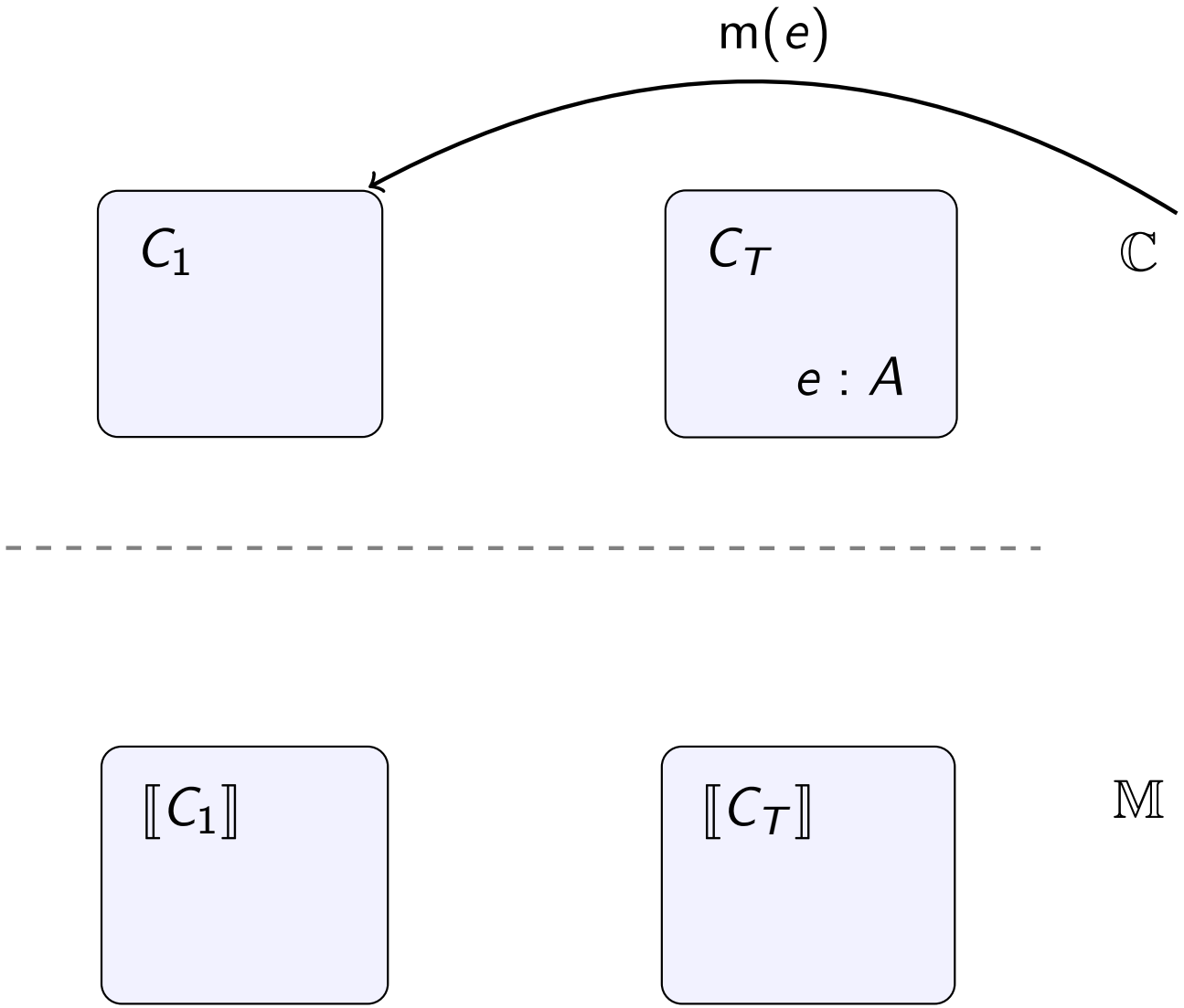
Object Faking



Object Faking



Object Faking



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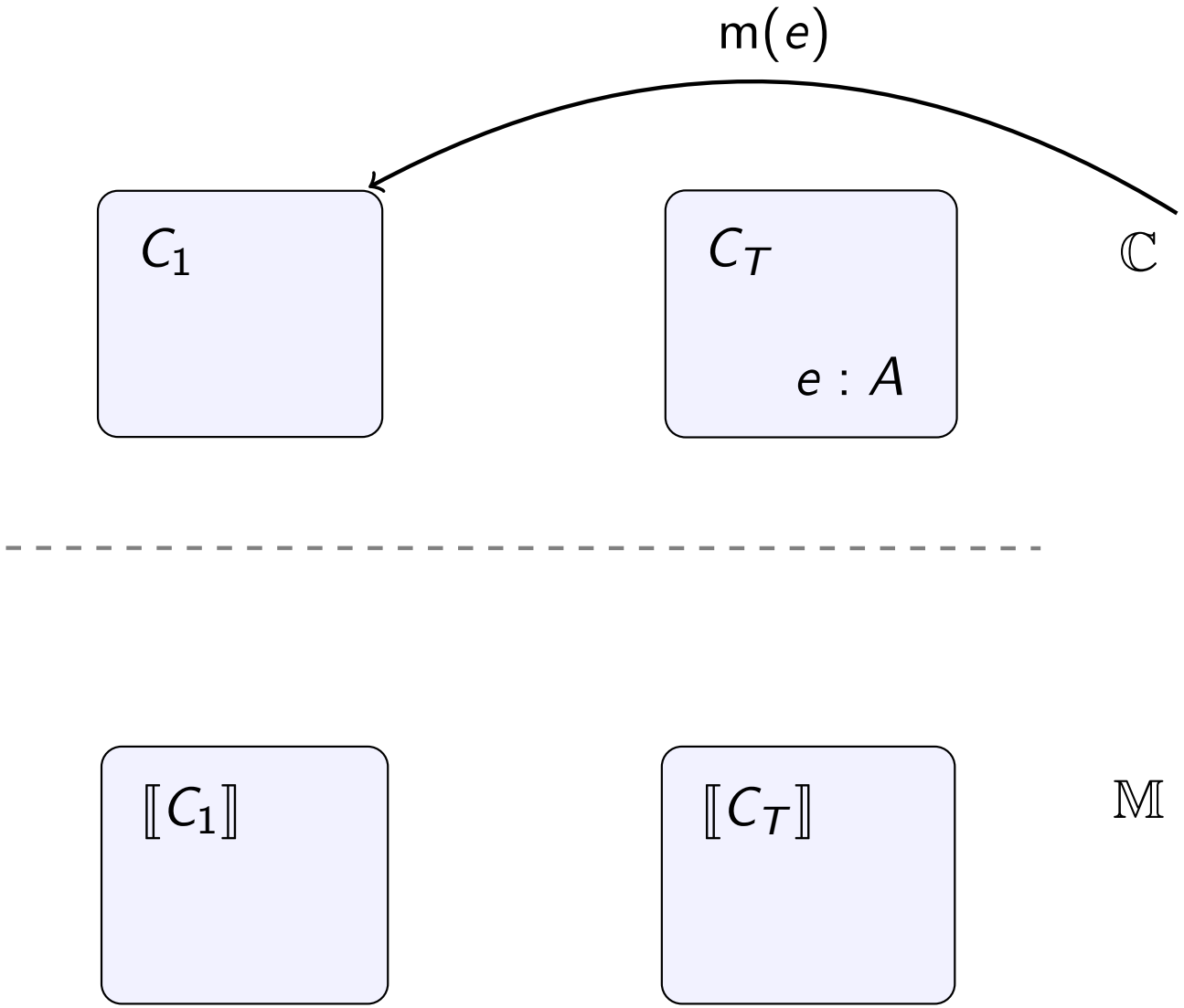

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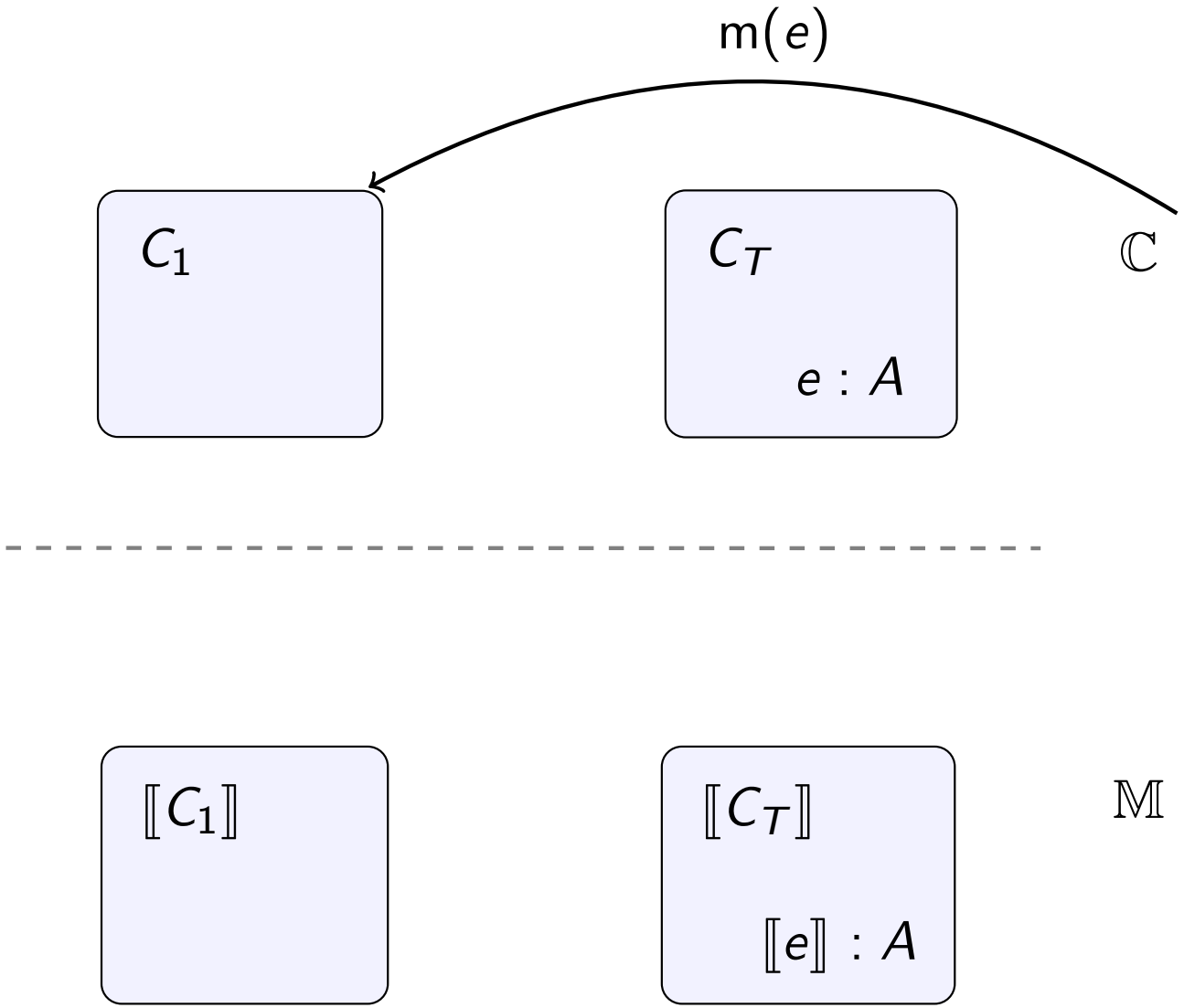
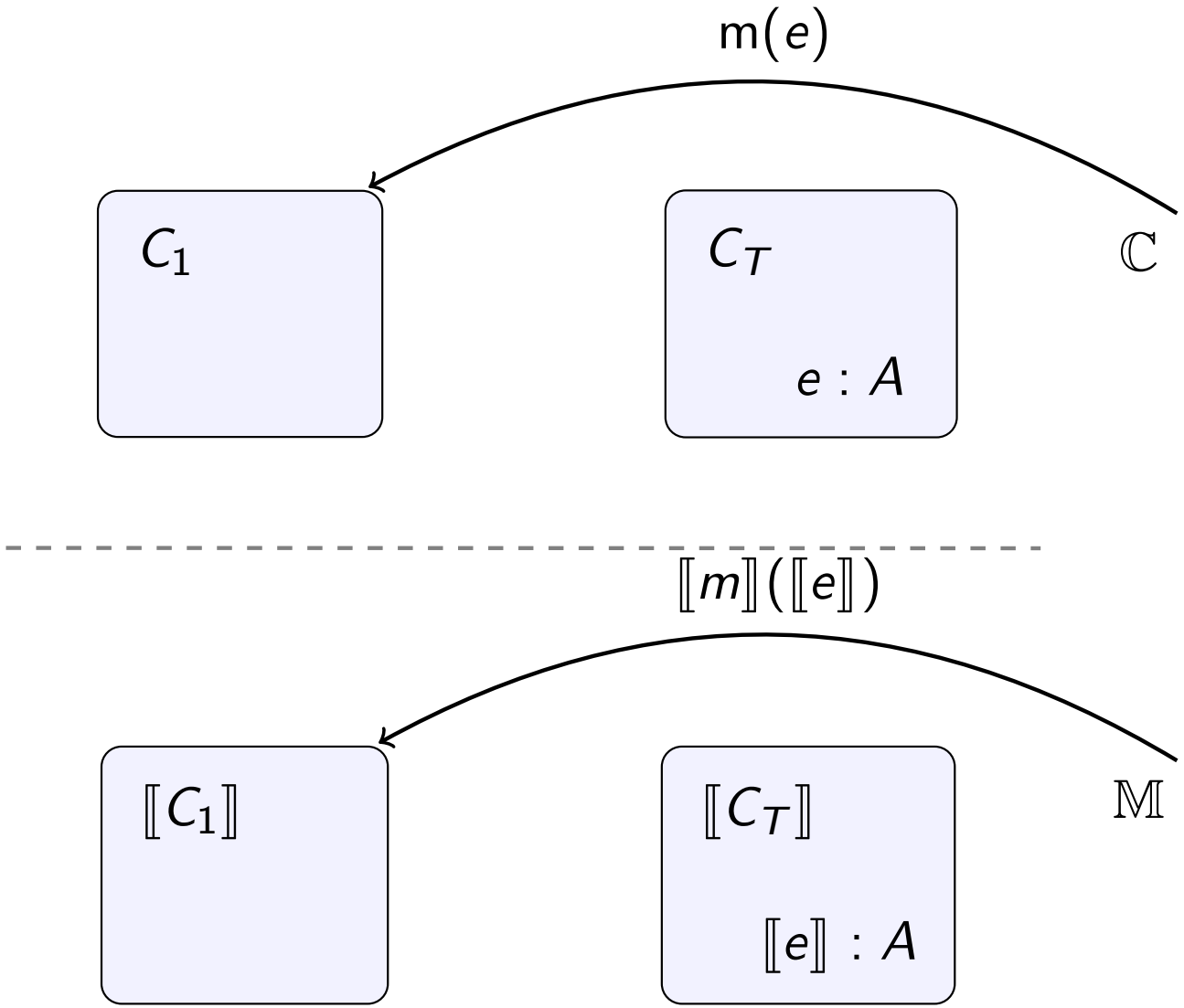
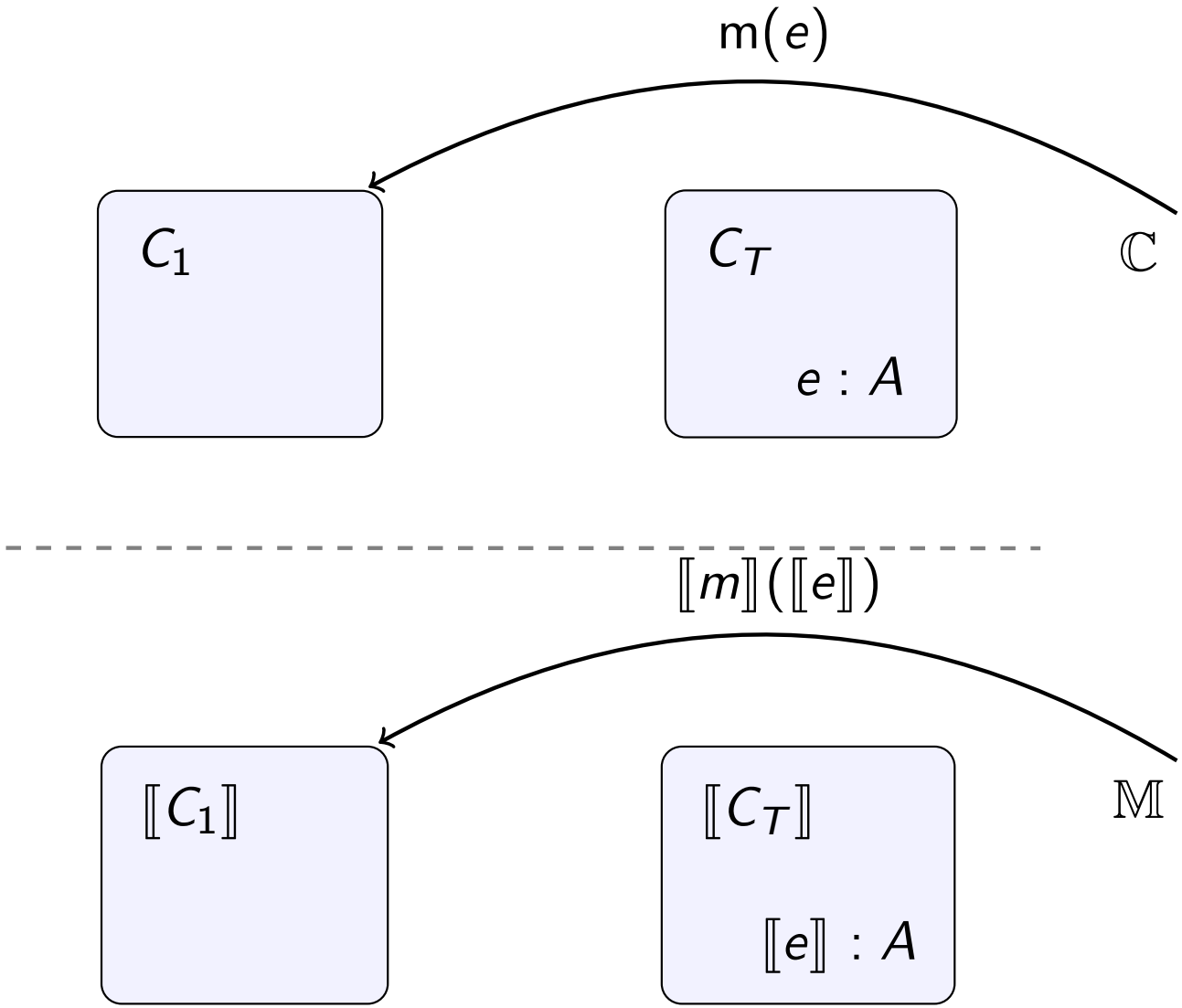


Object Faking



$e = \texttt{null}$
or obj : A

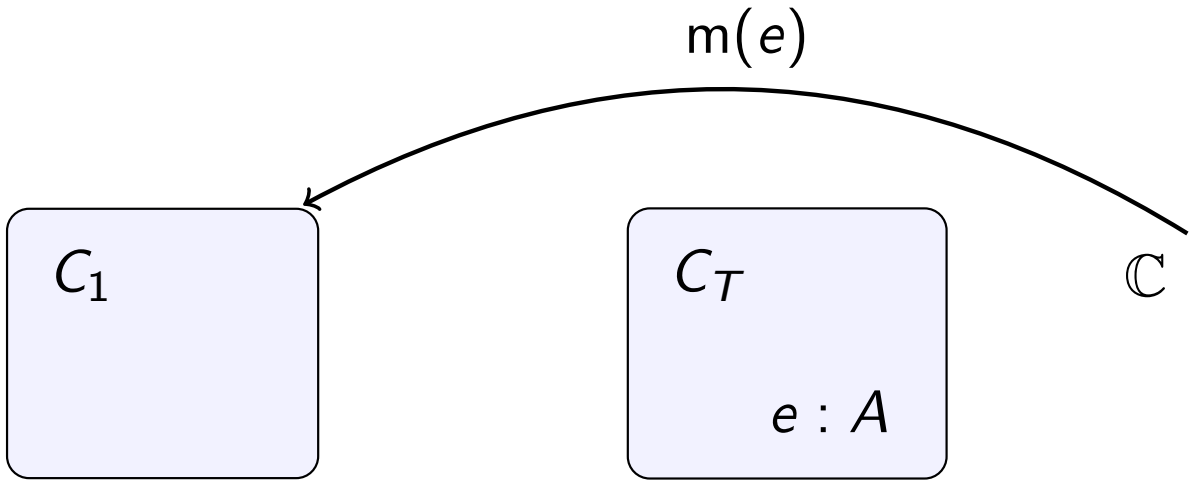
Object Faking



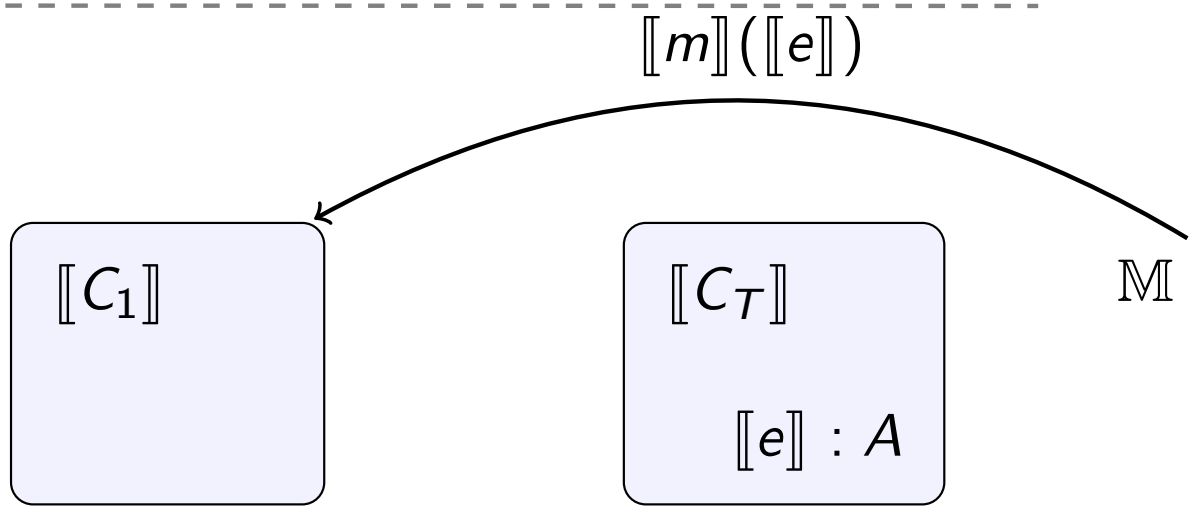
$e = \texttt{null}$
or obj : A

$[\![e]\!] = [\![\texttt{null}]\!]$
or obj : A

Object Faking



$e = \texttt{null}$
or obj : A



$[\![e]\!] = [\![\texttt{null}]\!]$
or obj : A
or obj : $B \not<: A$
or garbage

General Point

- problems always arising when two components are considered

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- no existing secure compiler deals with linking between compiled components

Outline

Solutions

- Protected modules architectures

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- Protected modules architectures [read, Intel SGX]

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- Protected modules architectures [read, Intel SGX] (isolation at assembly)

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- Protected modules architectures [read, Intel SGX] (isolation at assembly)
- Capability machines

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- Capability machines (subject/objects/operations at assembly)

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What is PMA?

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- the basis of several security-related works

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- deep encapsulation at the lowest level of abstraction
- the basis of several security-related works
- Intel is porting it into future processors (SGX)

Untyped Assembly + PMA

```
0x0001    call 0xb53
0x0002    movs r0 0x0b55
  ⋮
0x0b52    movs r0 0x0b55
0x0b53    call 0x0002
0x0b54    movs r0 0xeb54
0x0b55    ···
  ⋮
0xab00    jmp 0x0b53
  ⋮
0xeb52    movs r0 0xeb54
0xeb53    call 0xab02
0xeb54    ···
  ⋮
```

Untyped Assembly + PMA

```
0x0001    call 0xb53
0x0002    movs r0 0x0b55
   ⋮
0x0b52    movs r0 0x0b55
0x0b53    call 0x0002
0x0b54    movs r0 0xeb54
0x0b55    ...
   ⋮
0xab00    jmp 0x0b53
   ⋮
0xeb52    movs r0 0xeb54
0xeb53    call 0xab02
0xeb54    ...
   ⋮
```

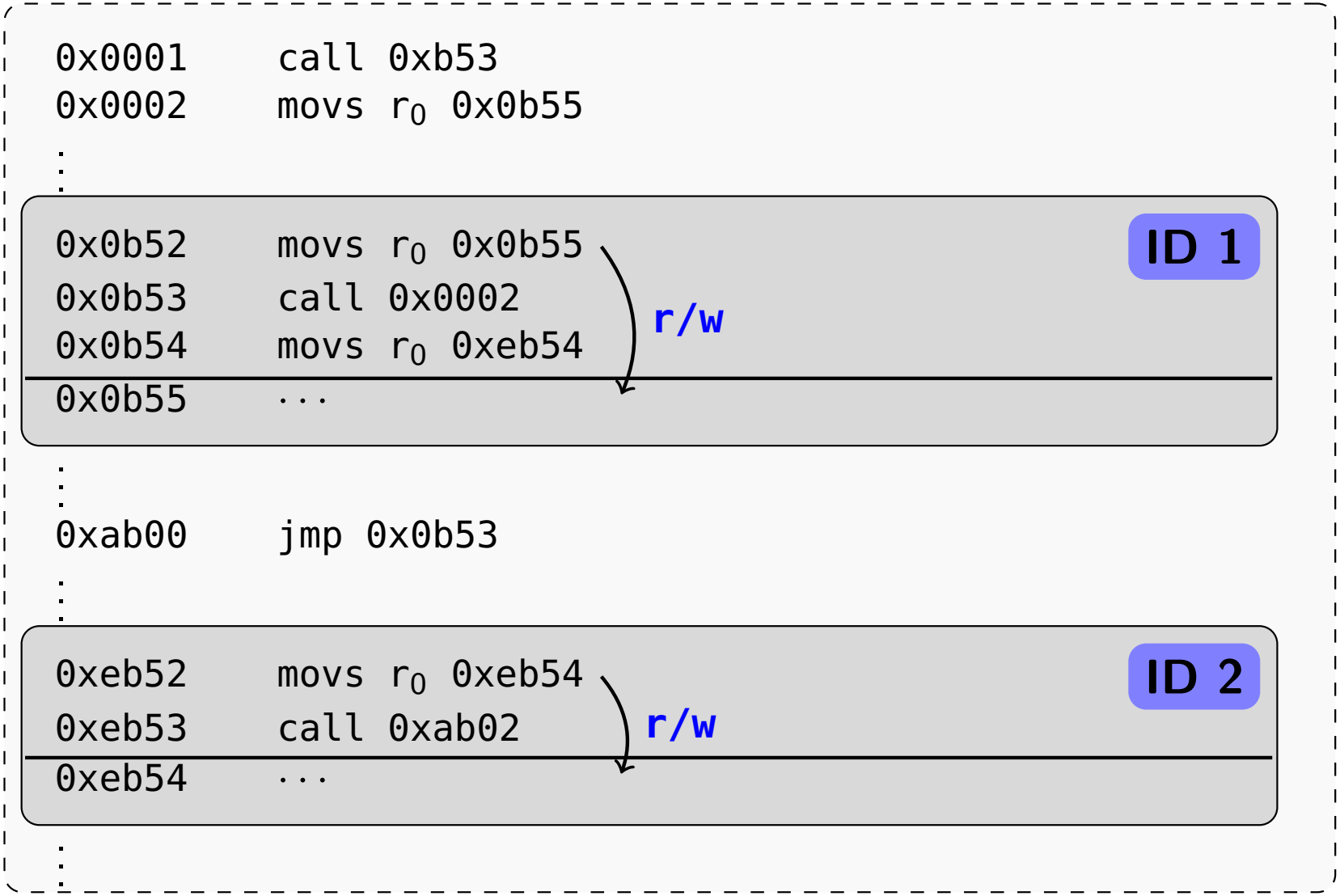
ID 1

ID 2

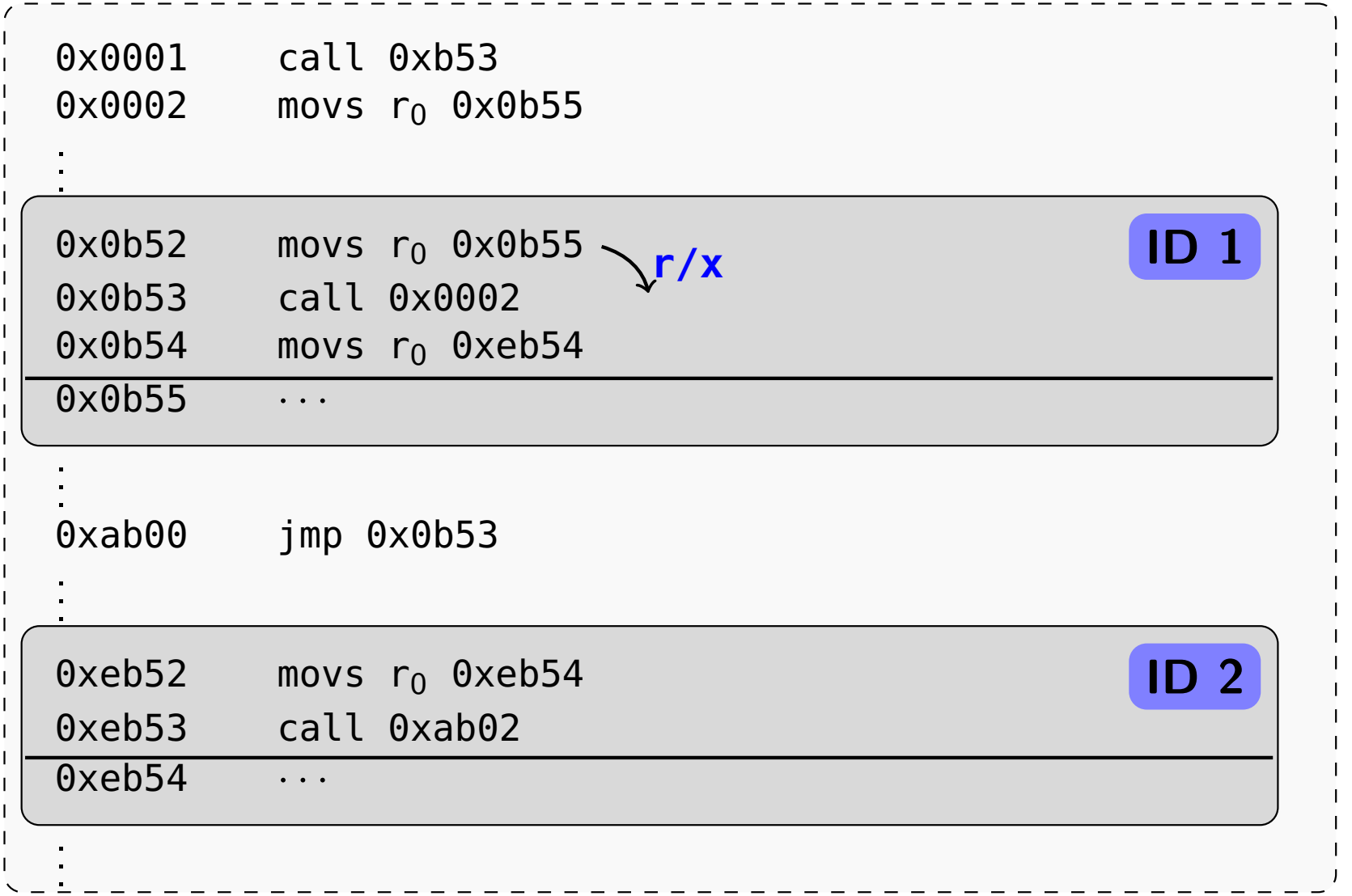
Untyped Assembly + PMA

```
0x0001    call 0xb53
0x0002    movs r0 0x0b55
   ⋮
0x0b52    movs r0 0x0b55        ID 1
0x0b53    call 0x0002
0x0b54    movs r0 0xeb54
0x0b55    ···
   ⋮
0xab00    jmp 0x0b53
   ⋮
0xeb52    movs r0 0xeb54        ID 2
0xeb53    call 0xab02
0xeb54    ···
   ⋮
```

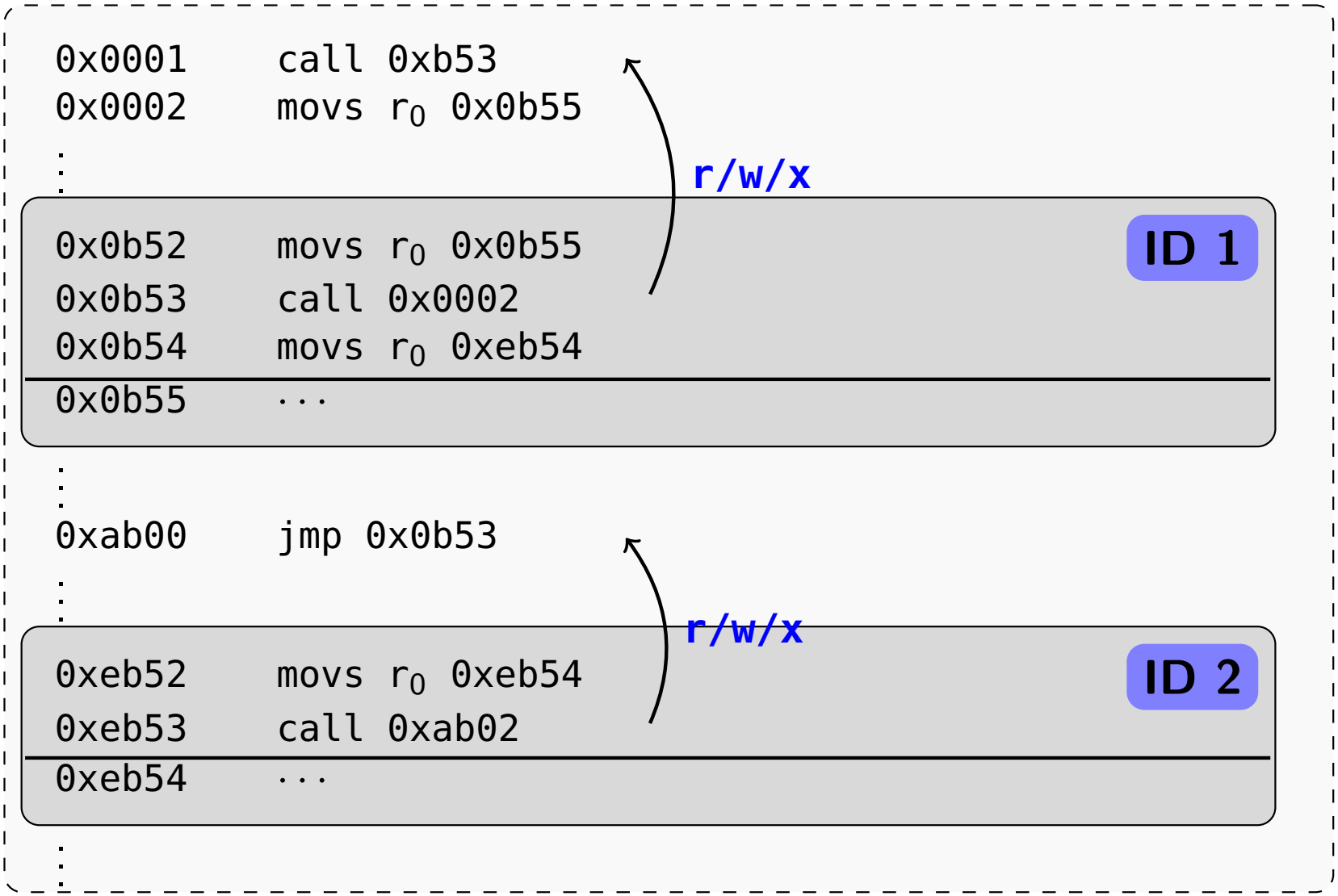
Untyped Assembly + PMA



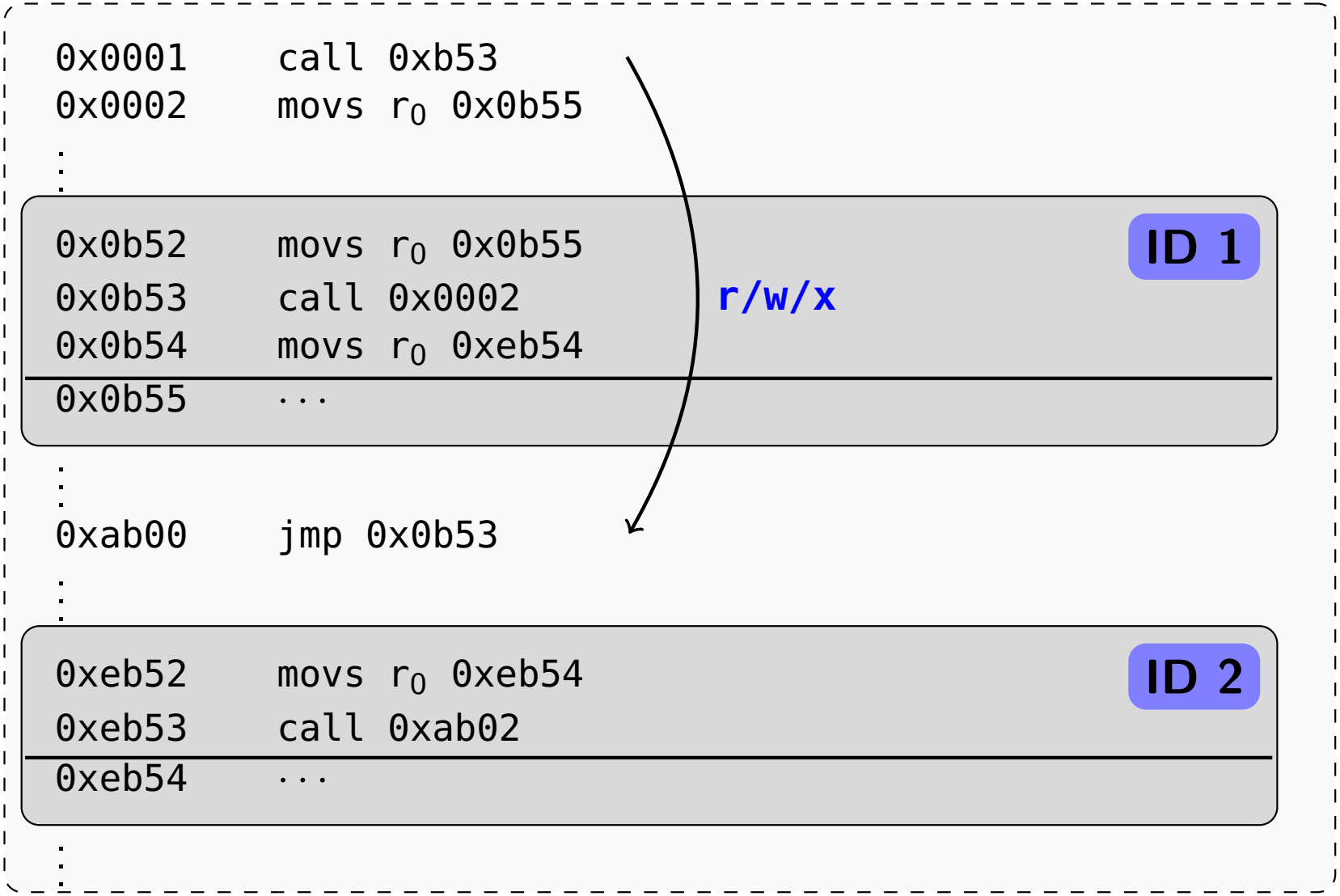
Untyped Assembly + PMA



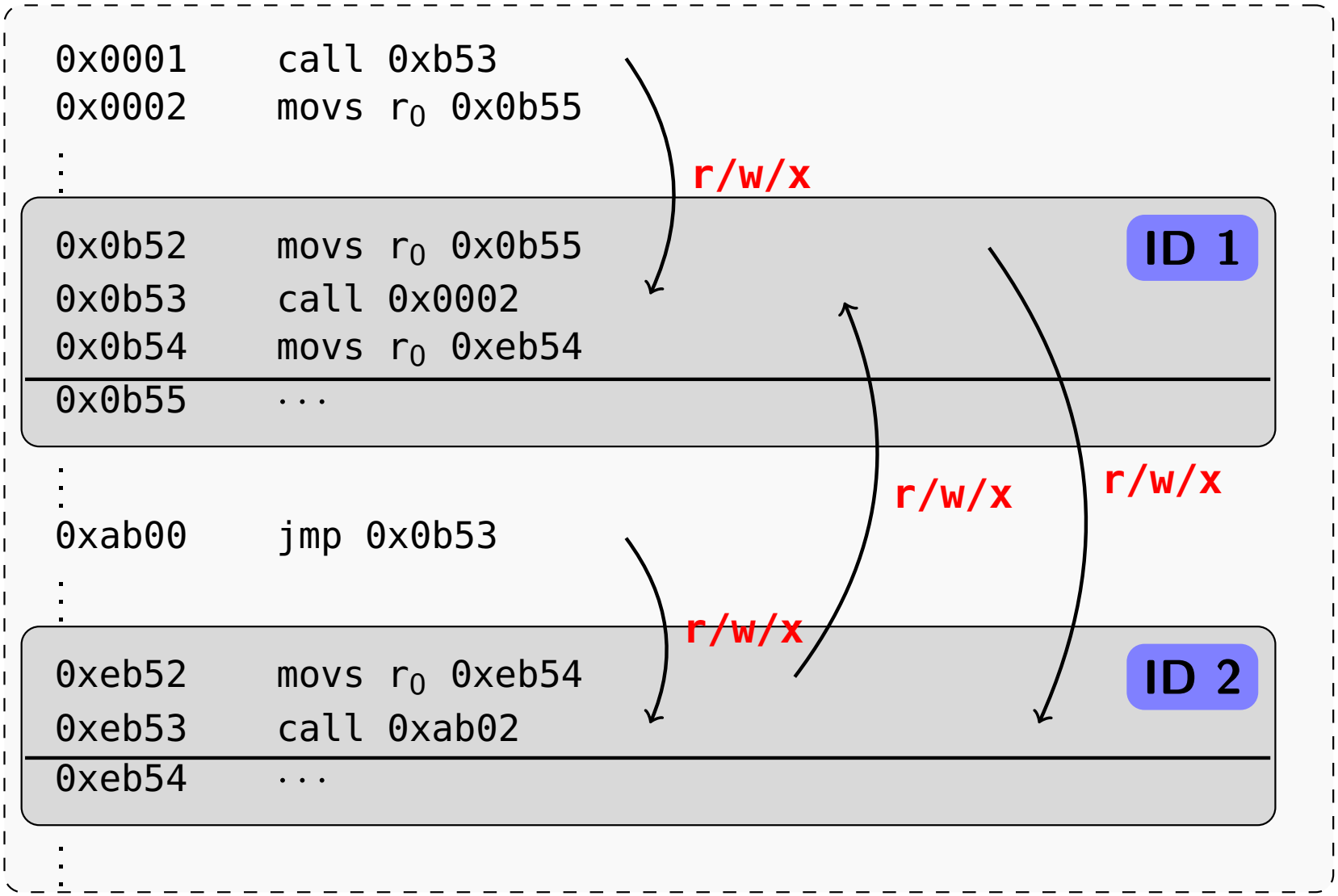
Untyped Assembly + PMA



Untyped Assembly + PMA



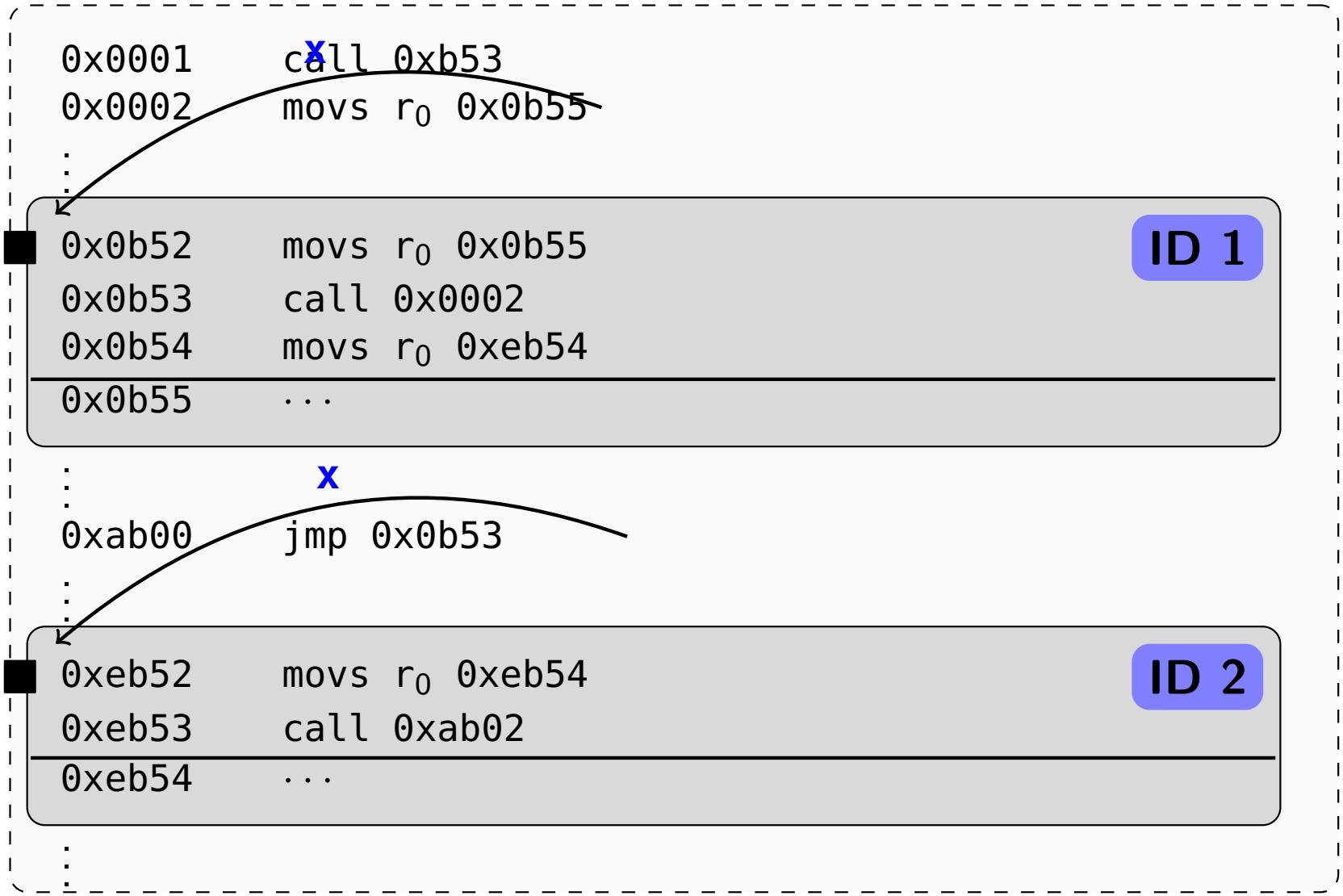
Untyped Assembly + PMA



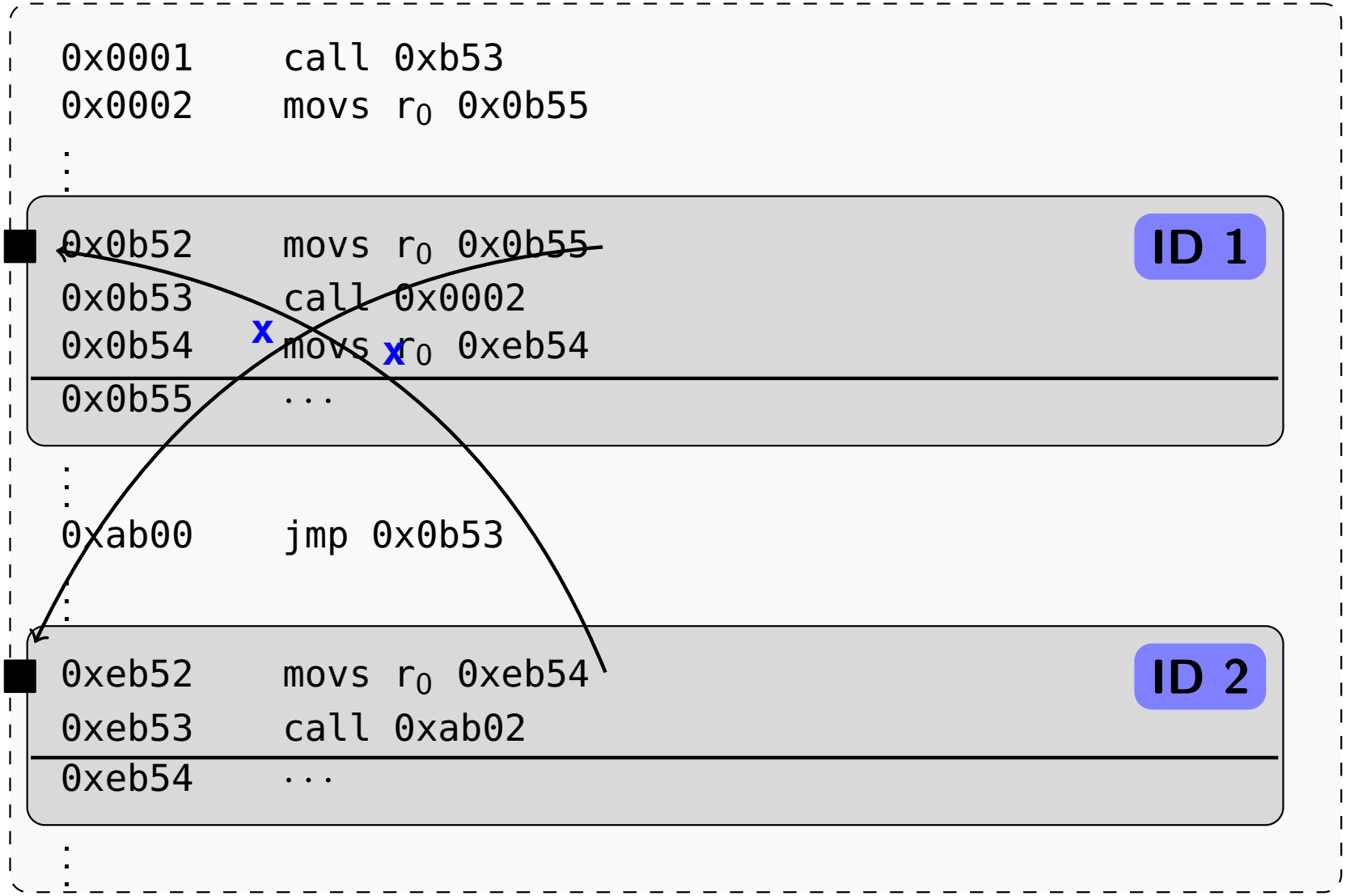
Untyped Assembly + PMA

```
0x0001    call 0xb53
0x0002    movs r0 0x0b55
   ⋮
0x0b52    movs r0 0x0b55        ID 1
0x0b53    call 0x0002
0x0b54    movs r0 0xeb54
0x0b55    ...
   ⋮
0xab00    jmp 0x0b53
   ⋮
0xeb52    movs r0 0xeb54        ID 2
0xeb53    call 0xab02
0xeb54    ...
   ⋮
```

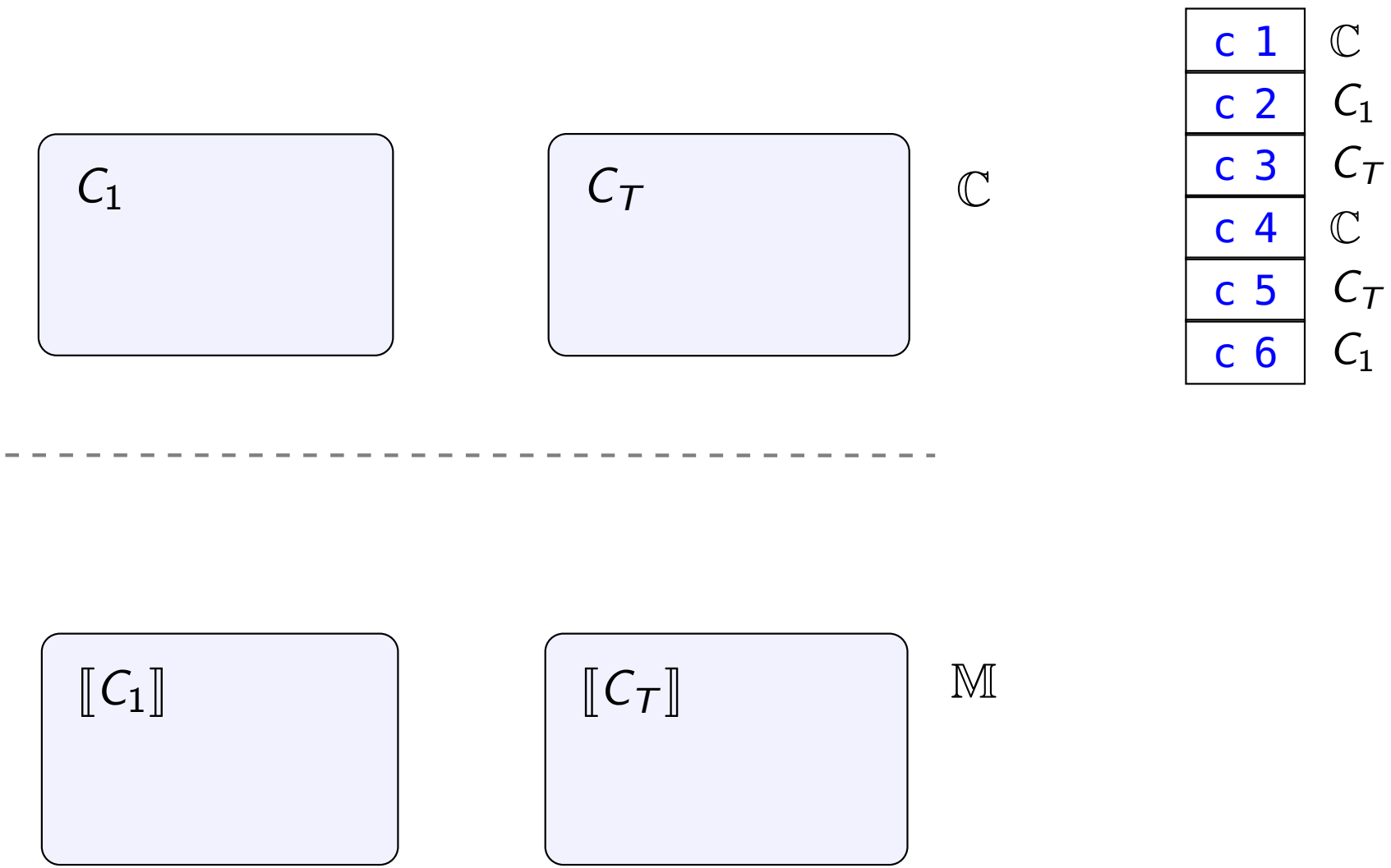
Untyped Assembly + PMA



Untyped Assembly + PMA



Addressing Call Stack Shortcutting



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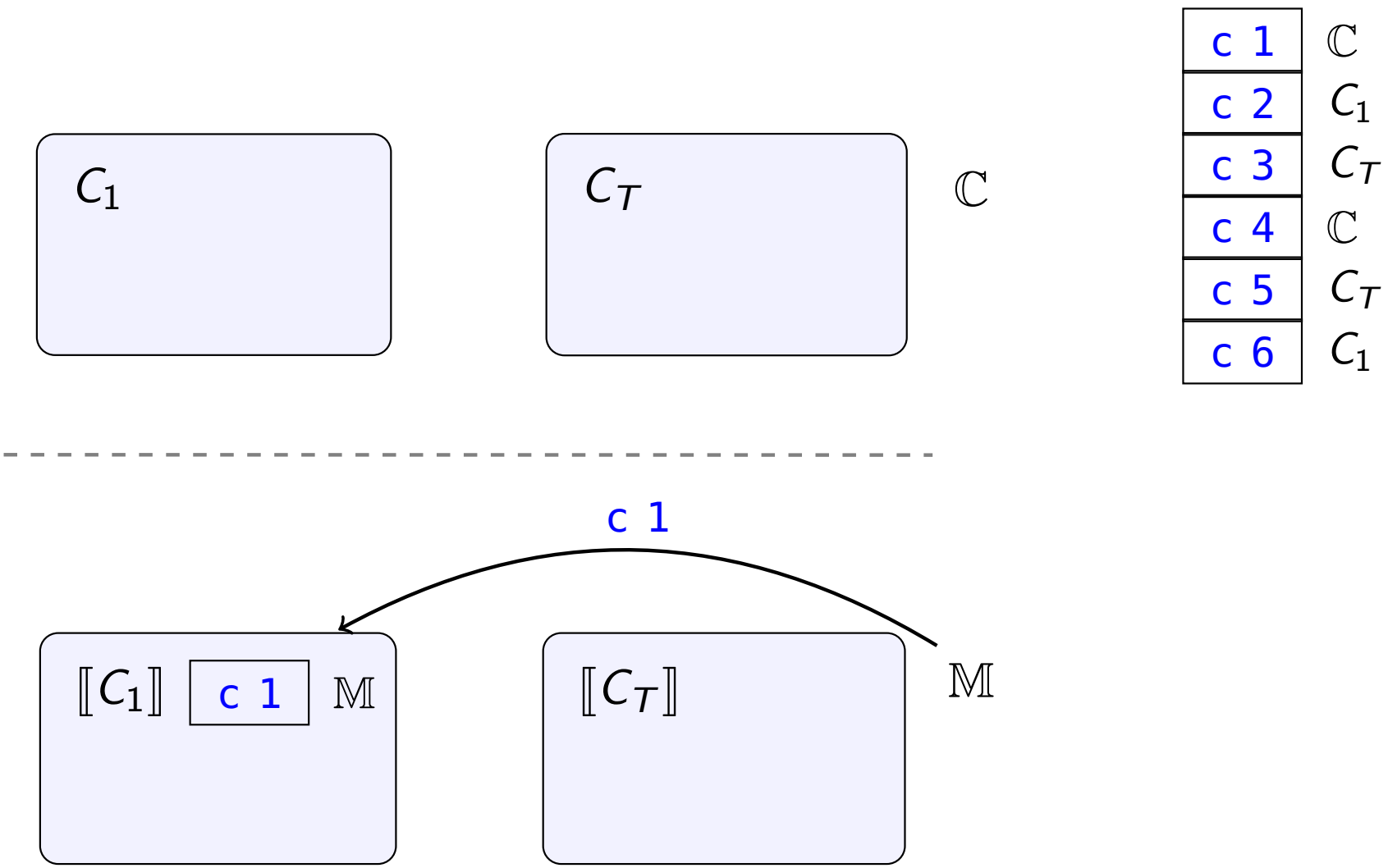

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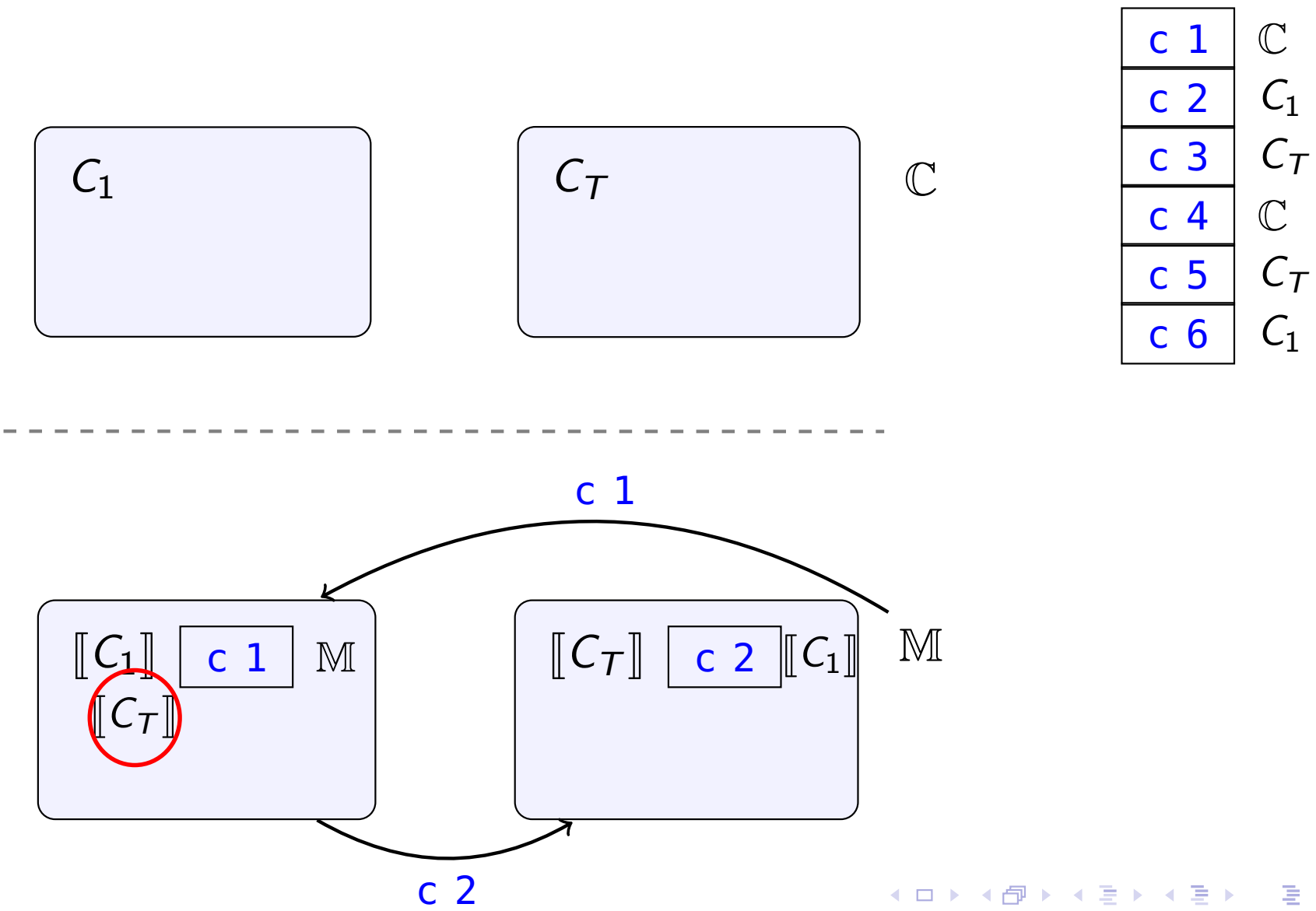
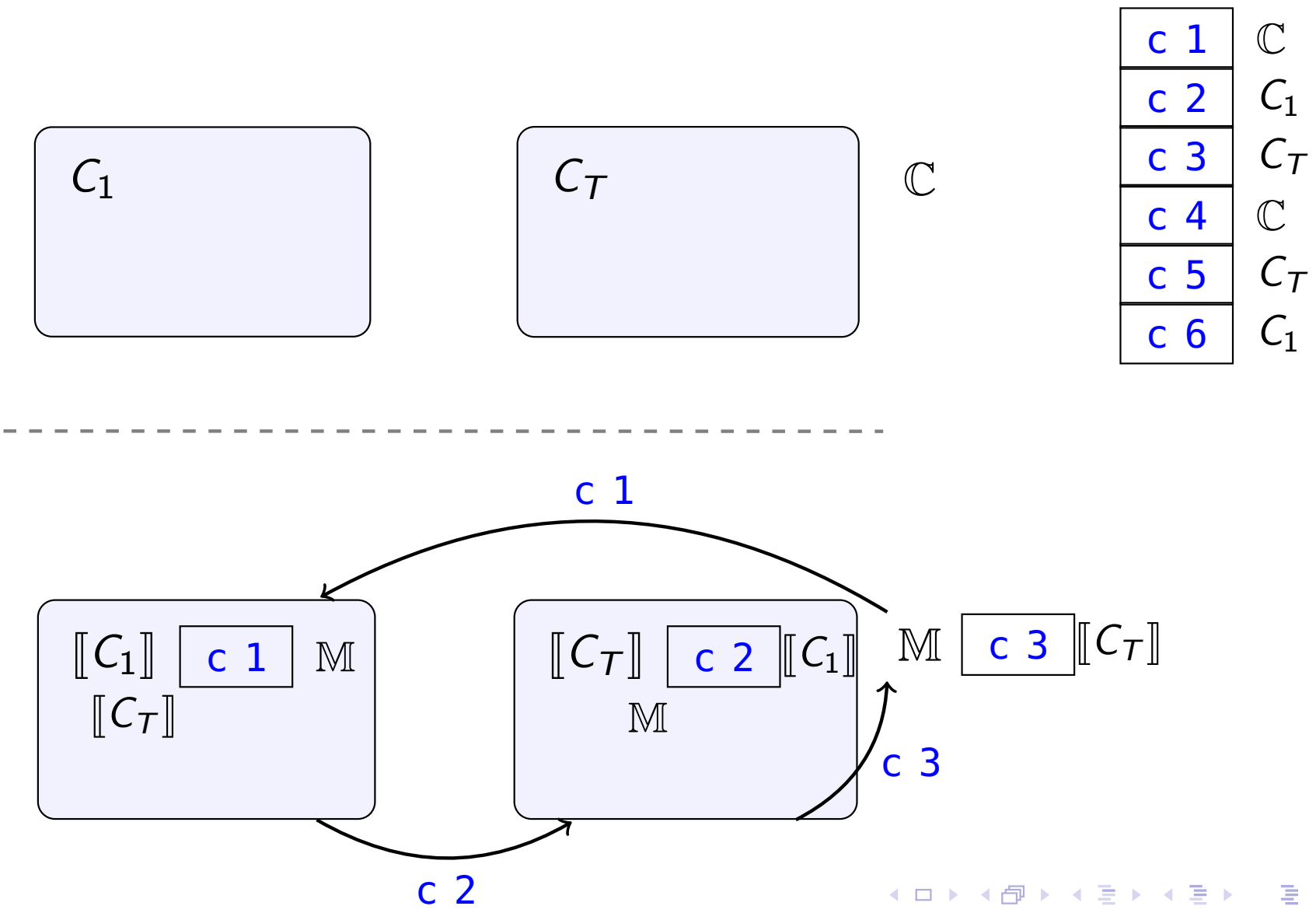
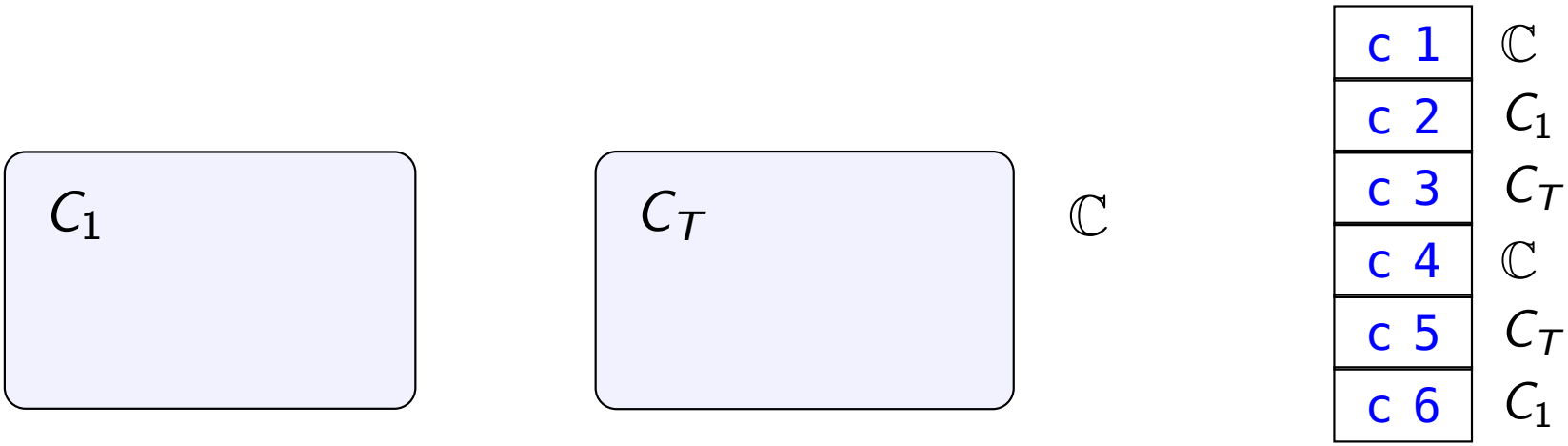


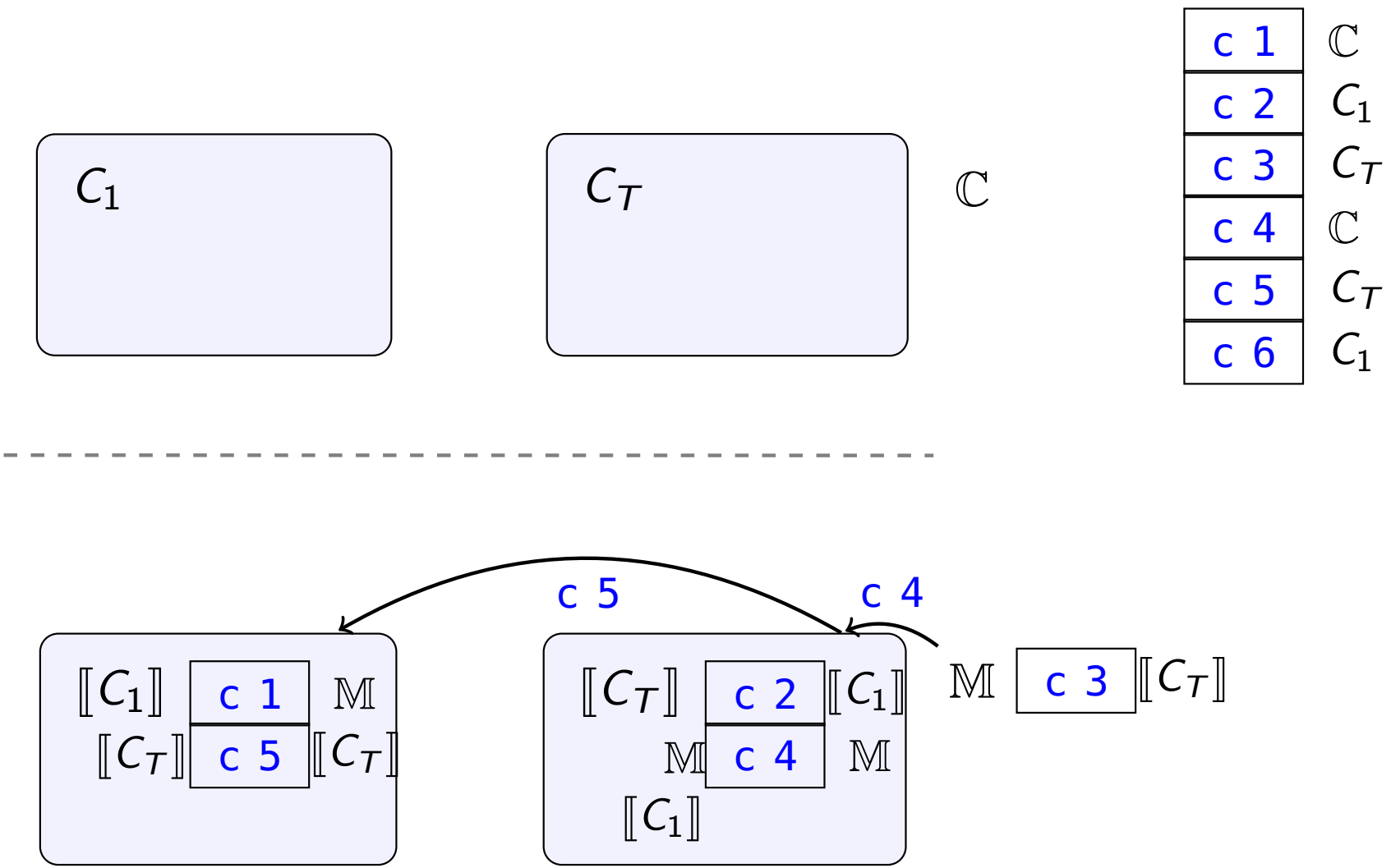
Addressing Call Stack Shortcutting



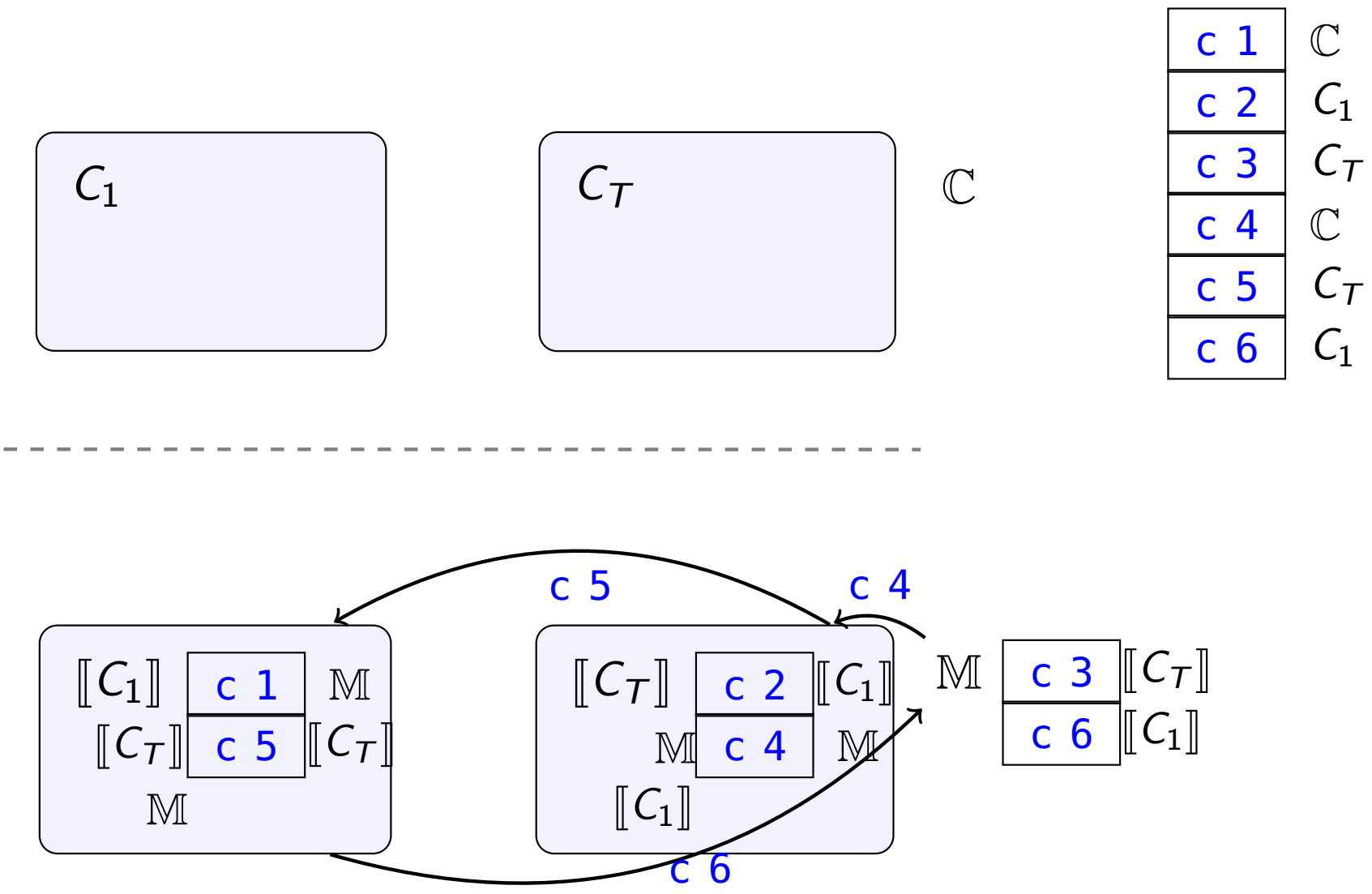
Addressing Call Stack Shortcutting



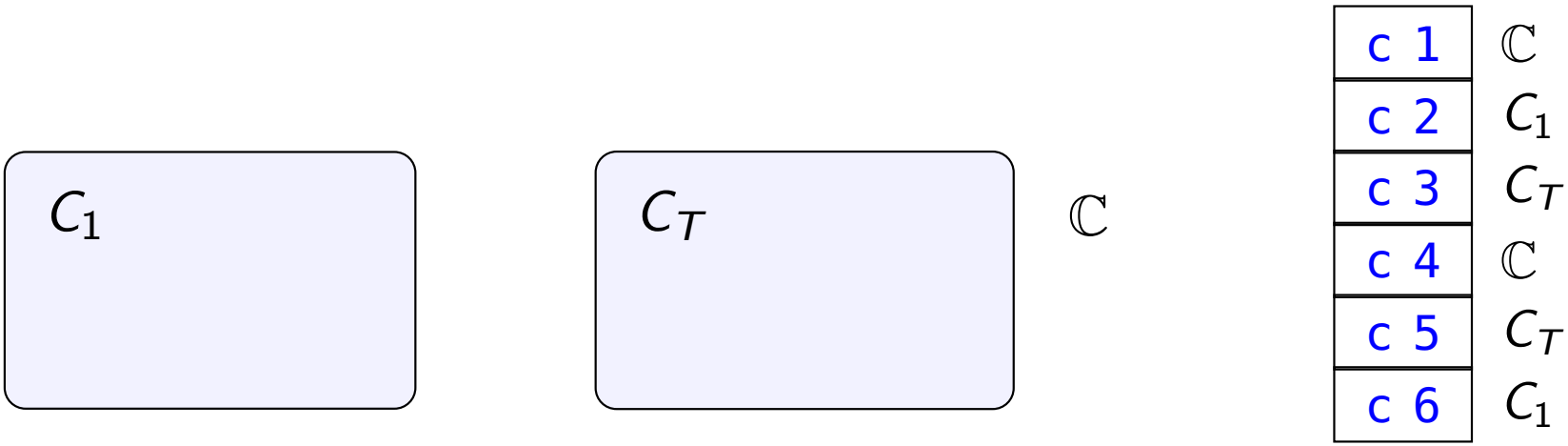
Addressing Call Stack Shortcutting



Addressing Call Stack Shortcutting



Addressing Call Stack Shortcutting



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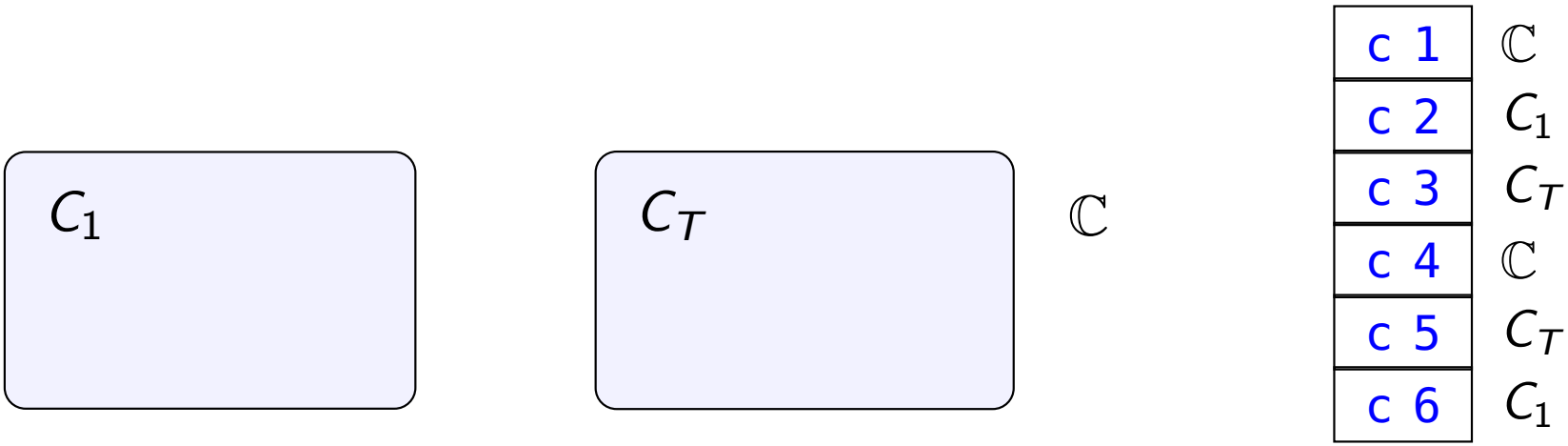

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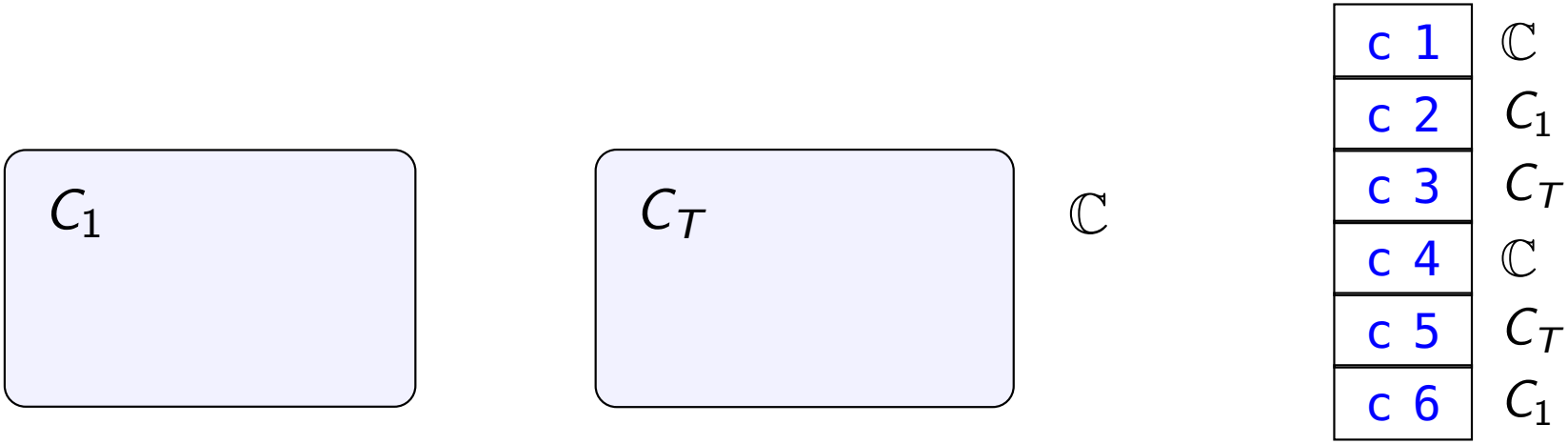

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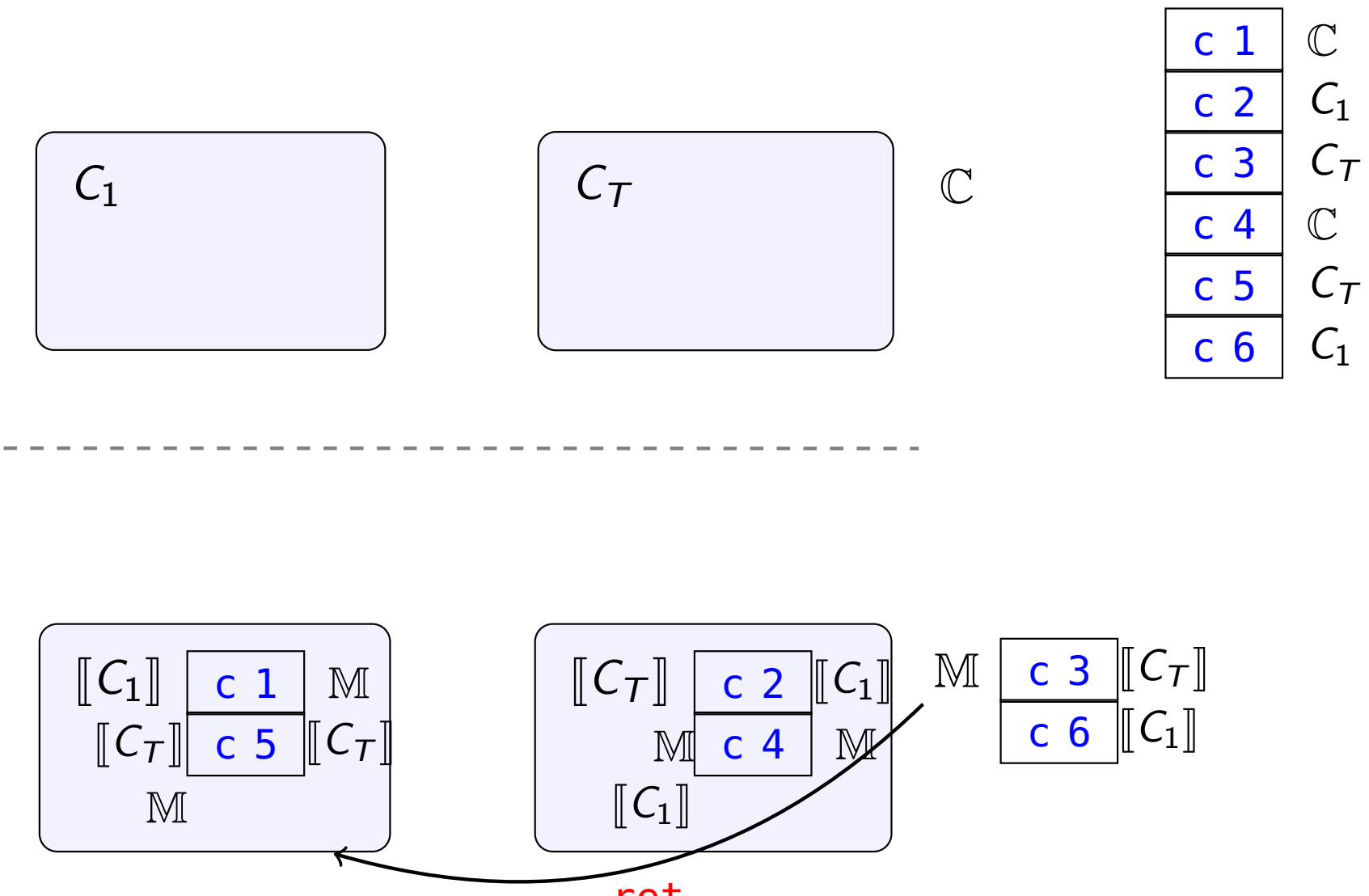

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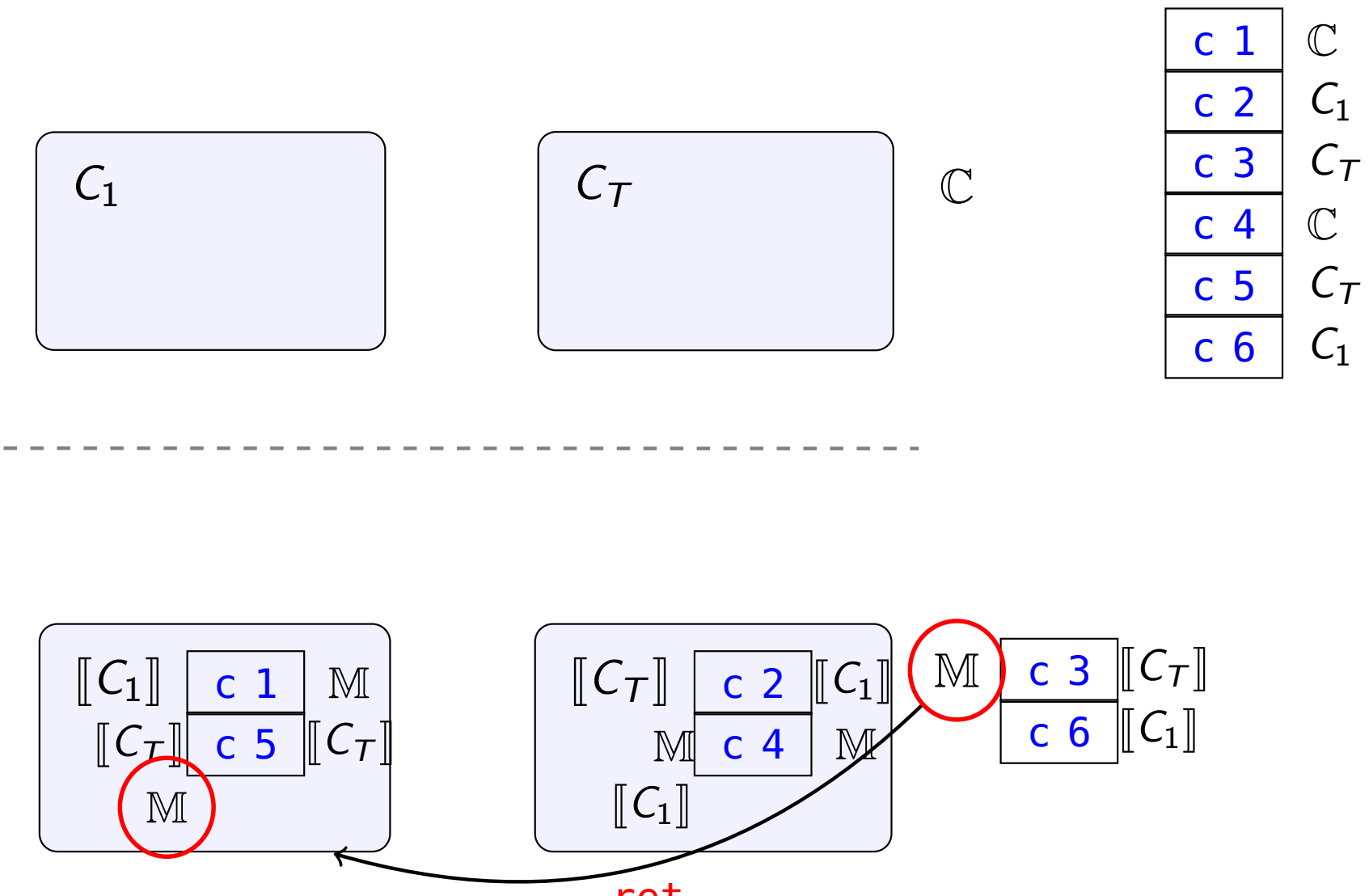

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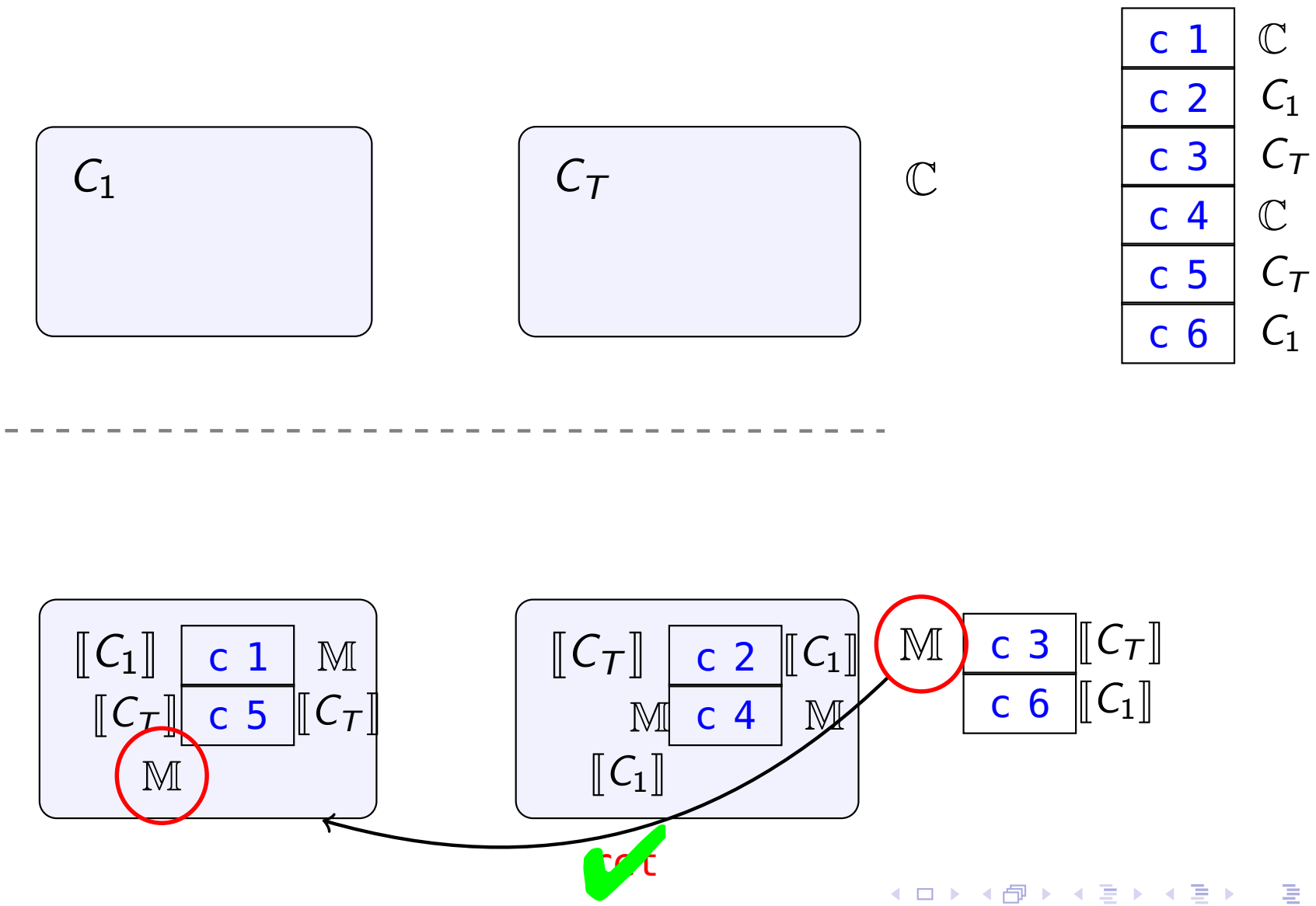
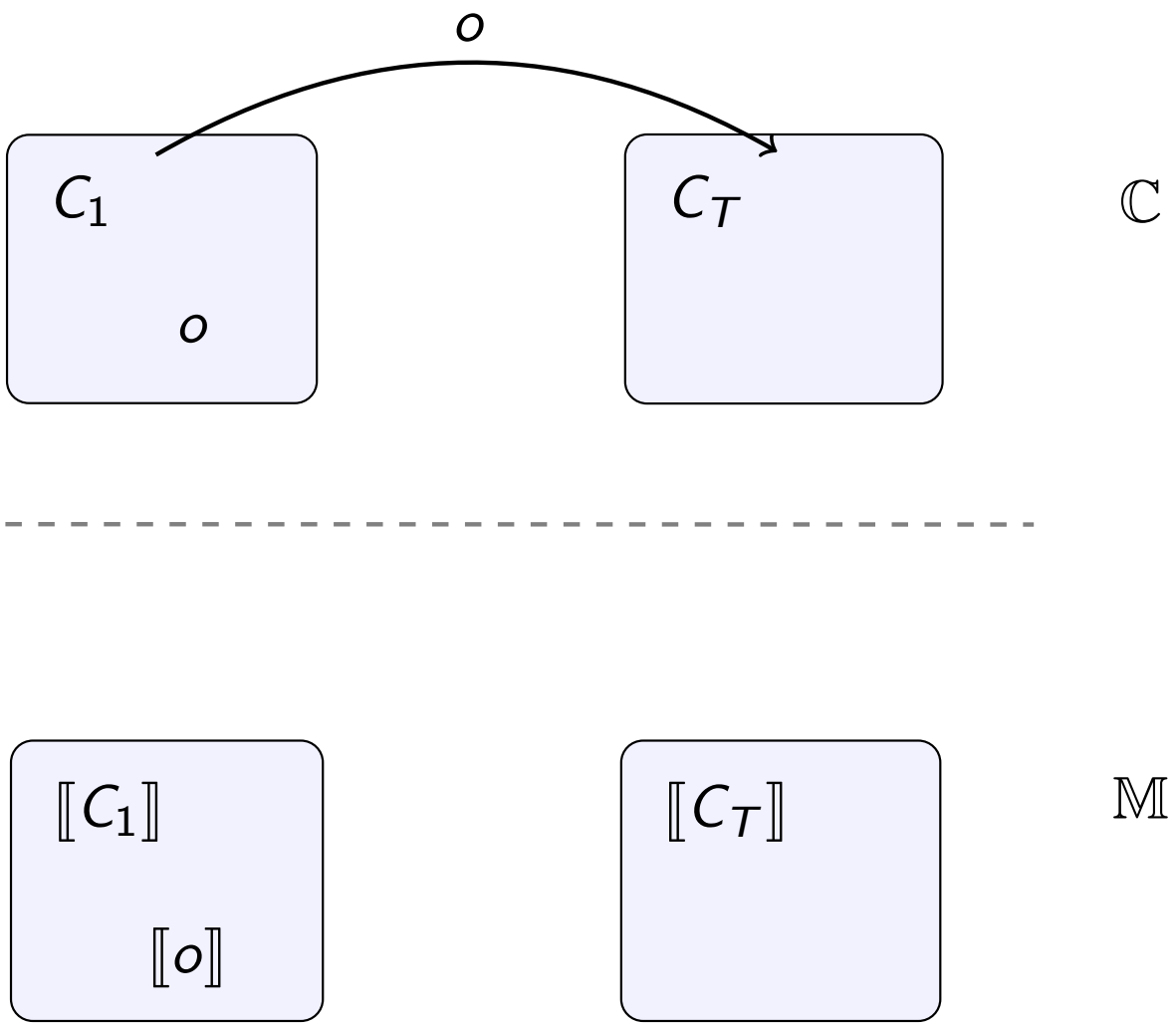
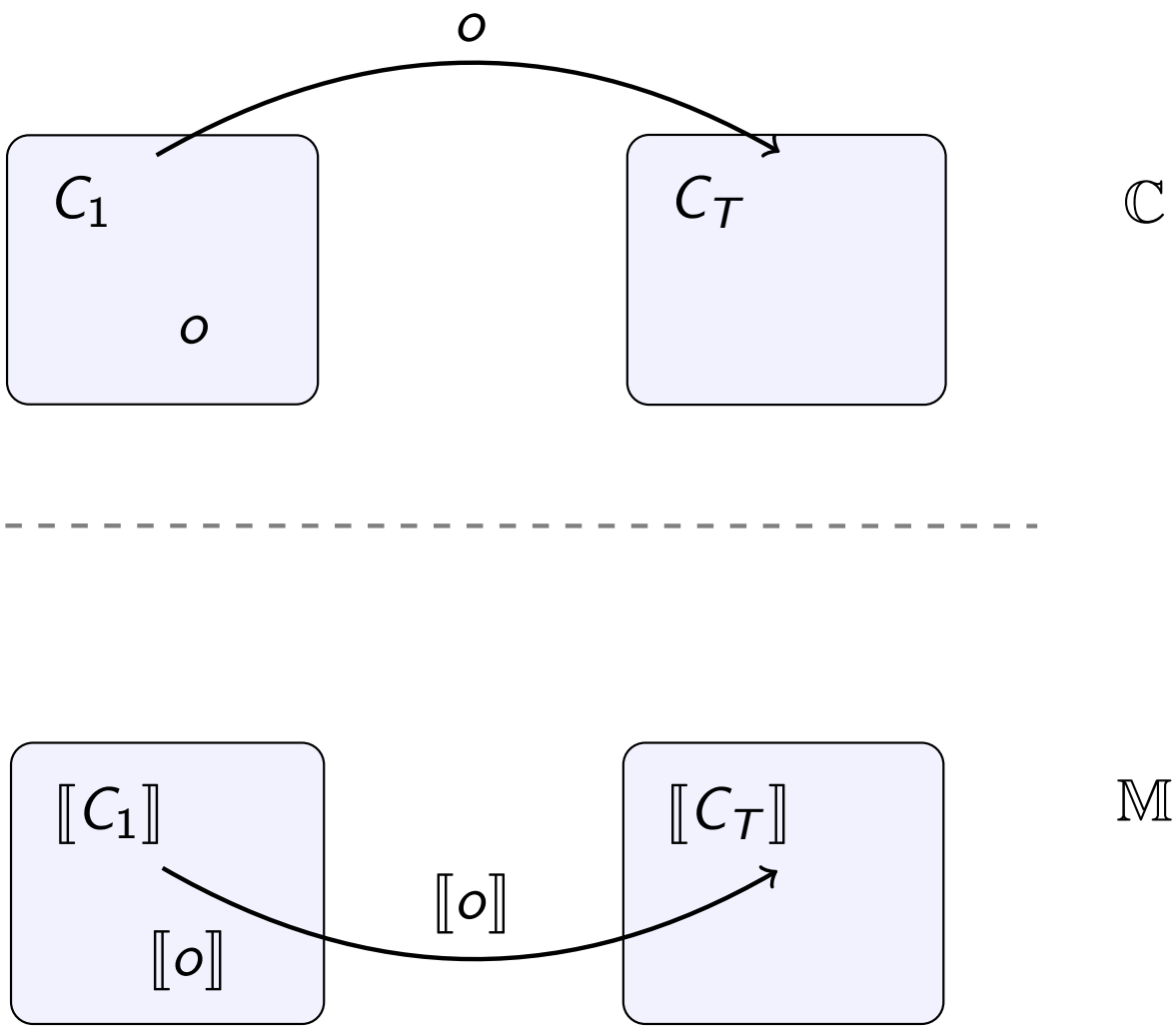


Addressing Object Guessing



Addressing Object Guessing



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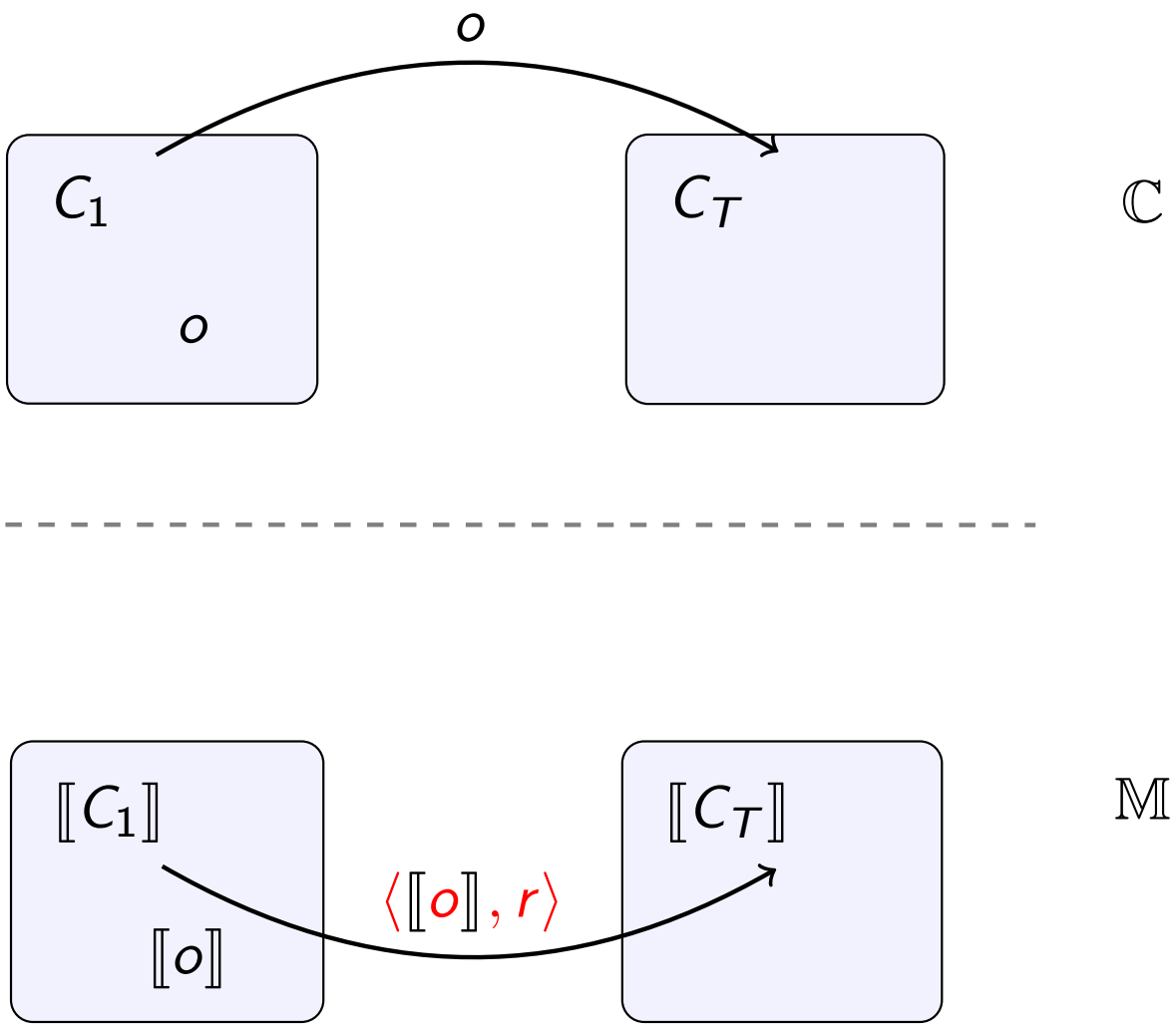

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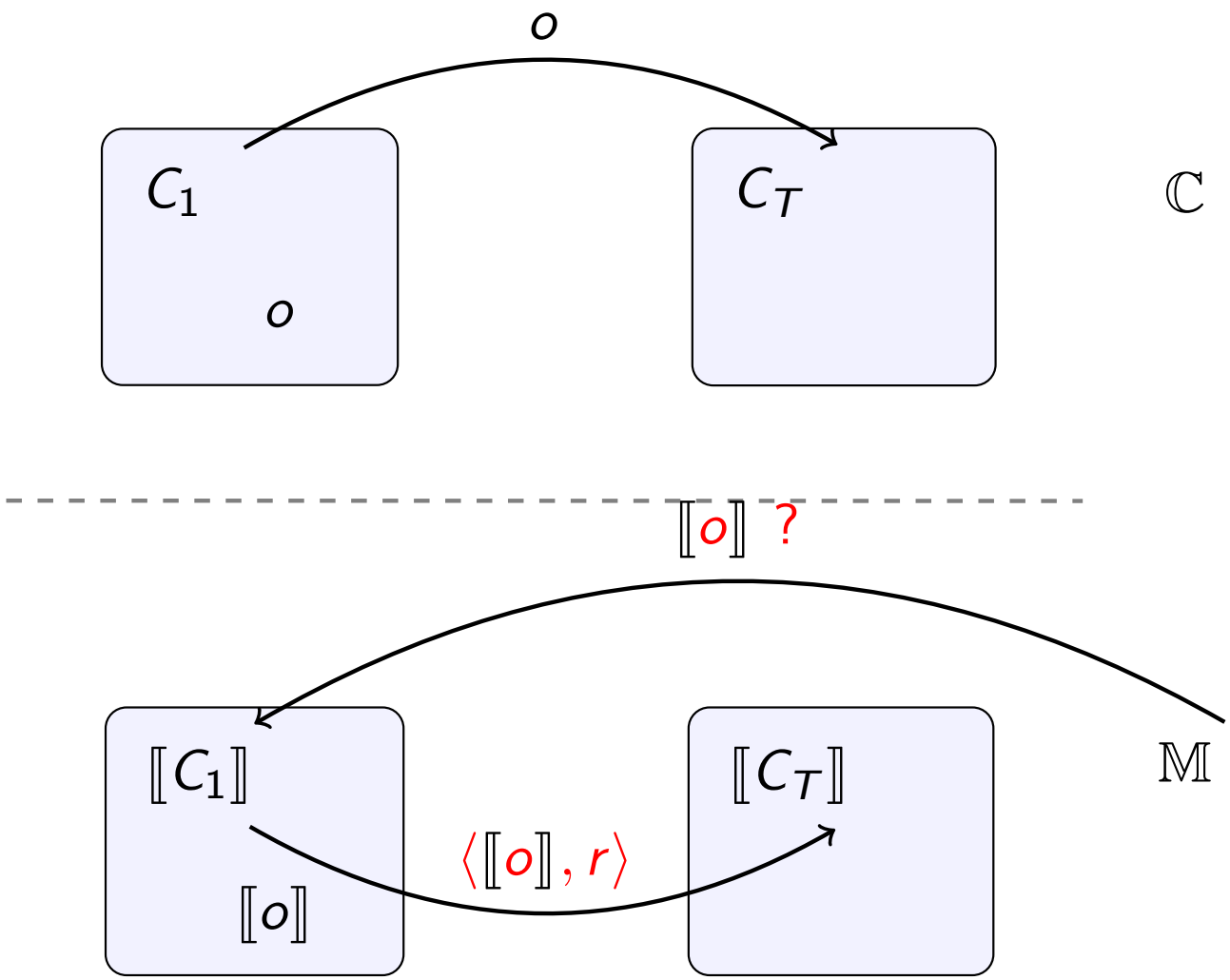
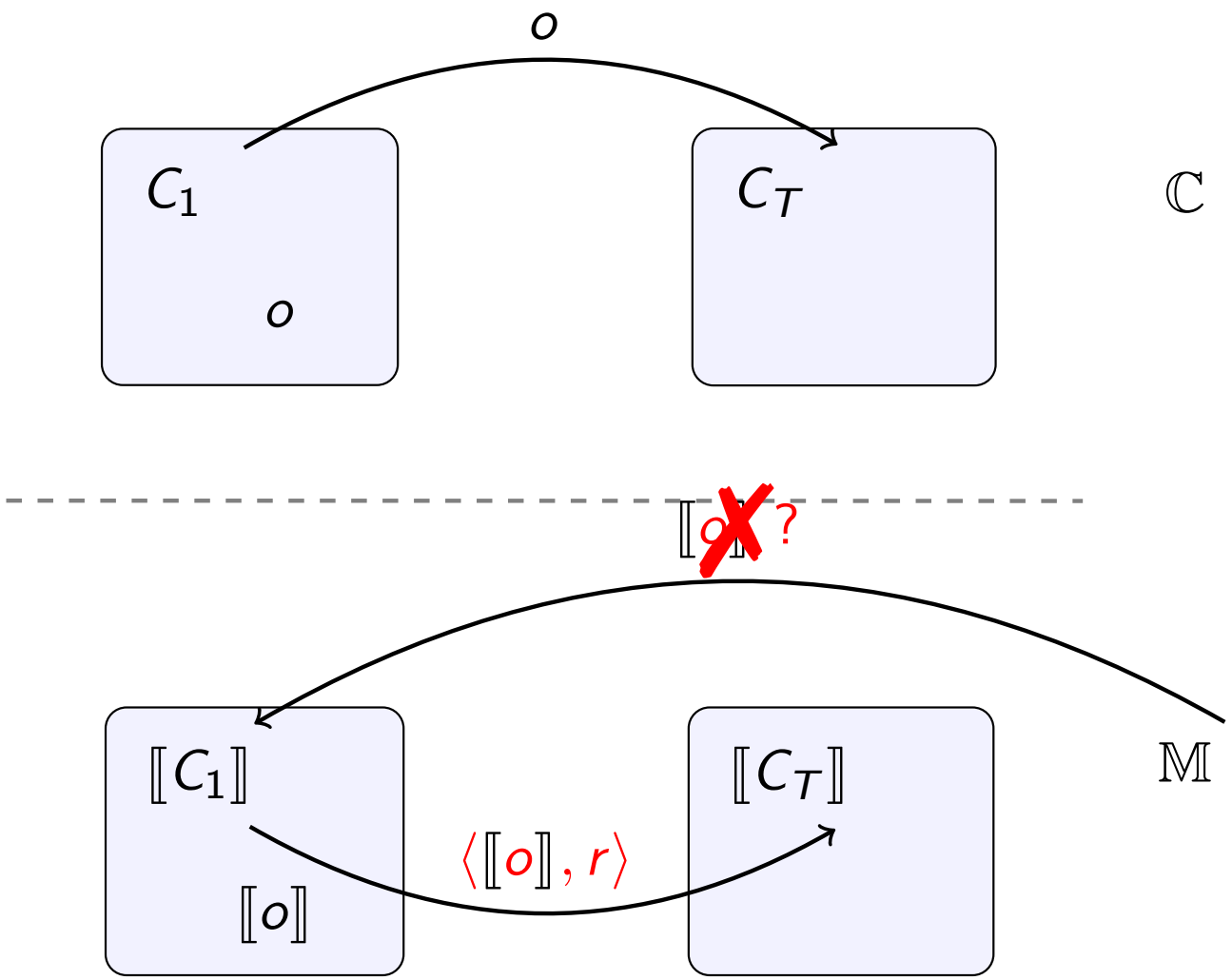
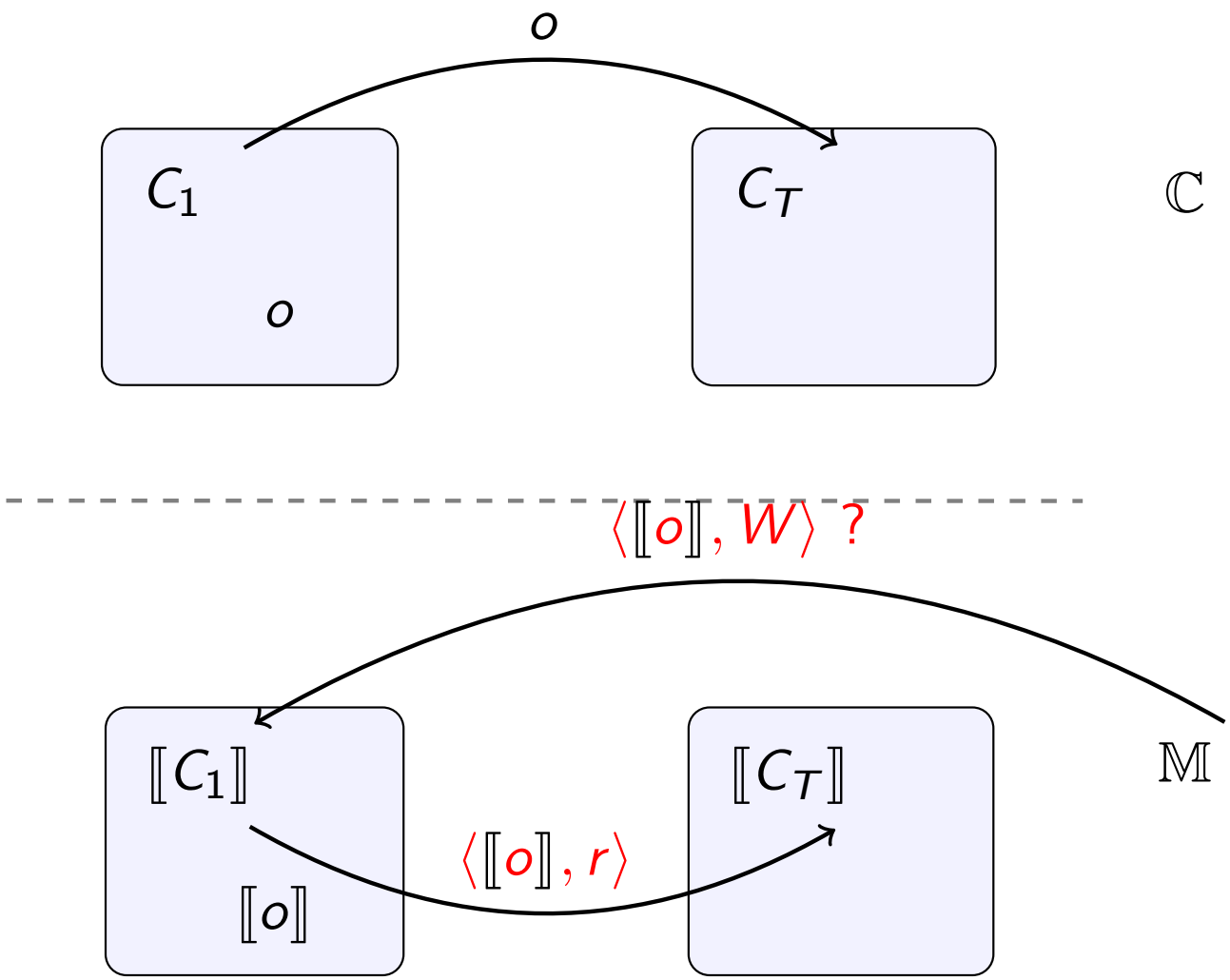


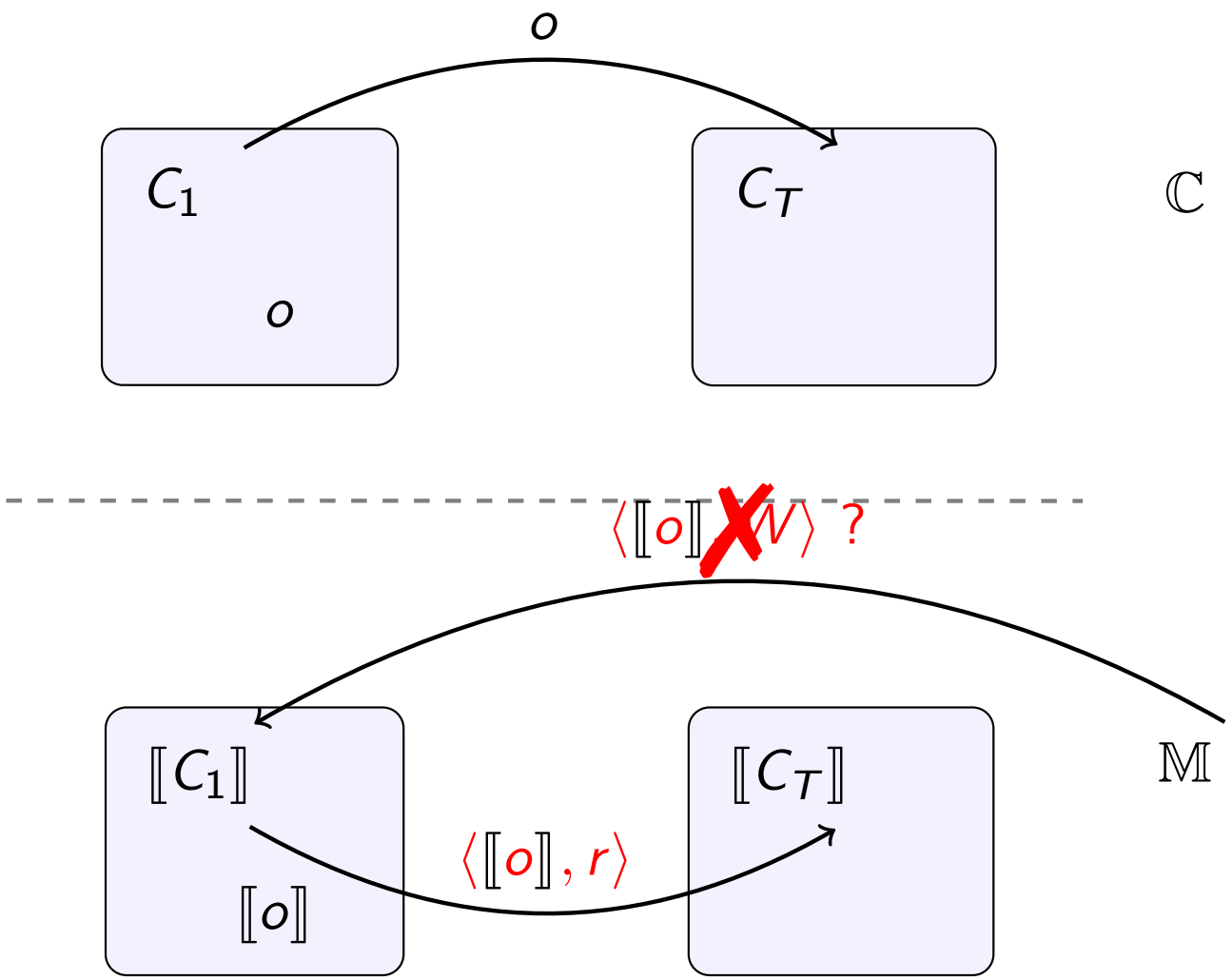
Addressing Object Guessing



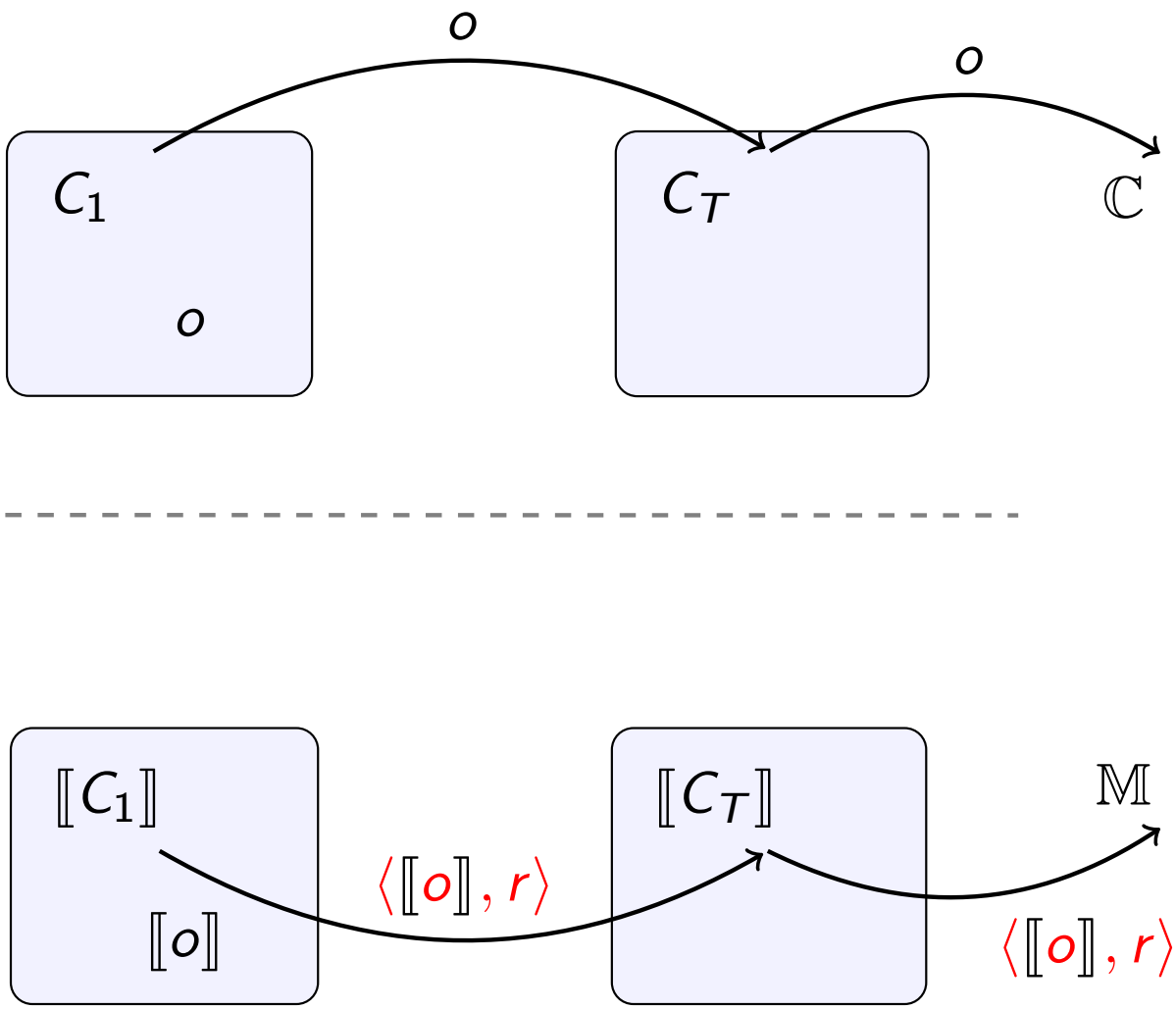
Addressing Object Guessing



Addressing Object Guessing



Addressing Object Guessing



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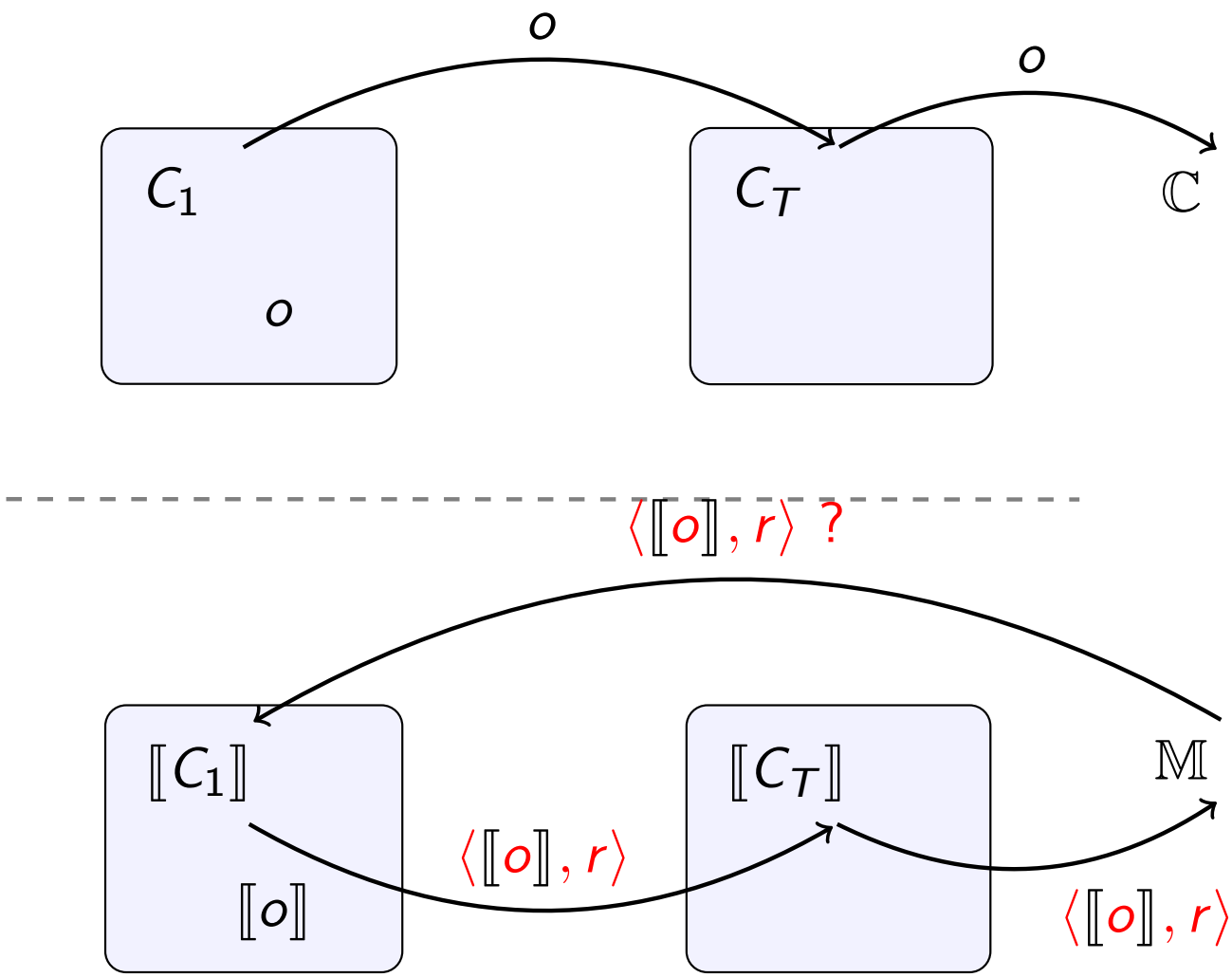
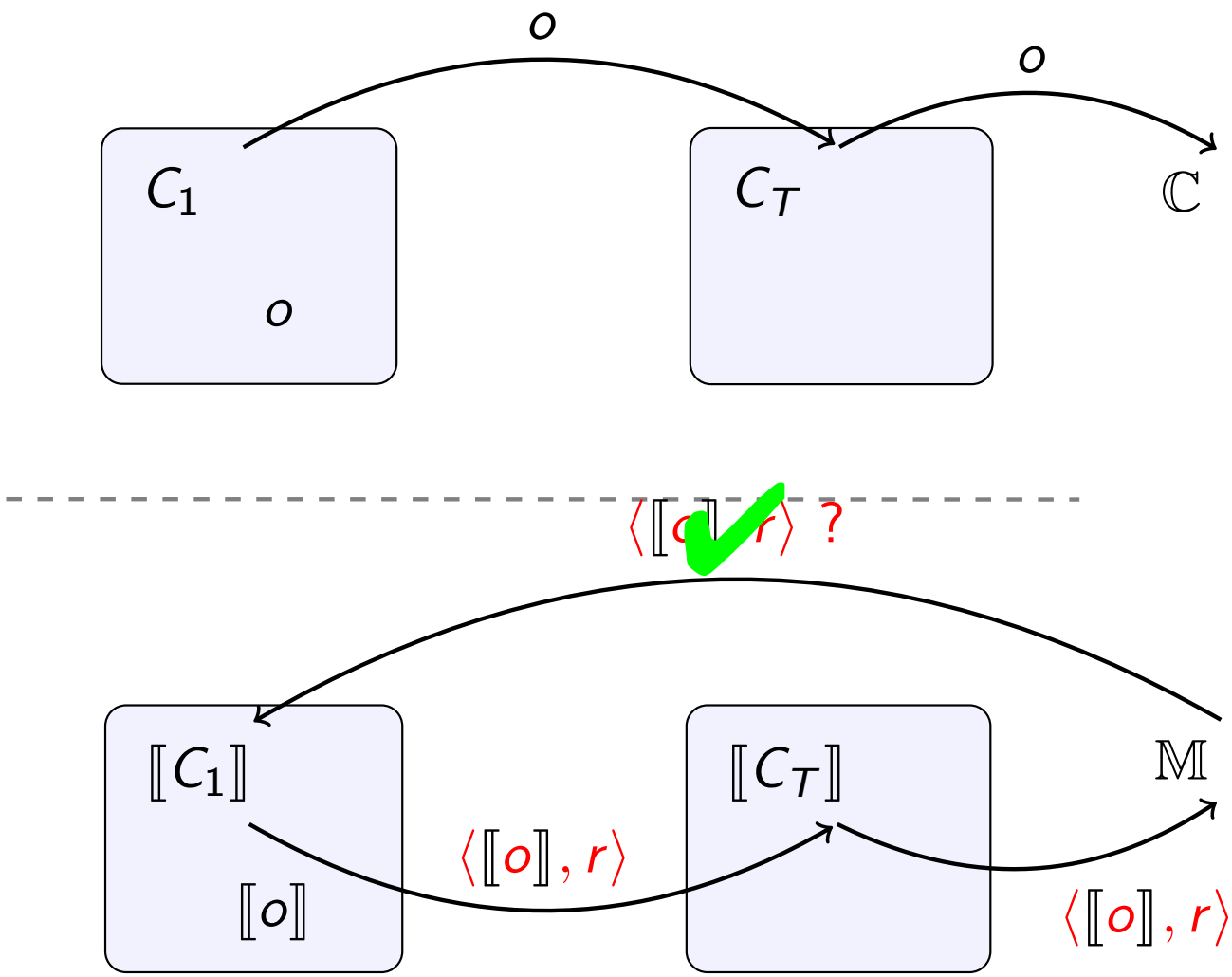
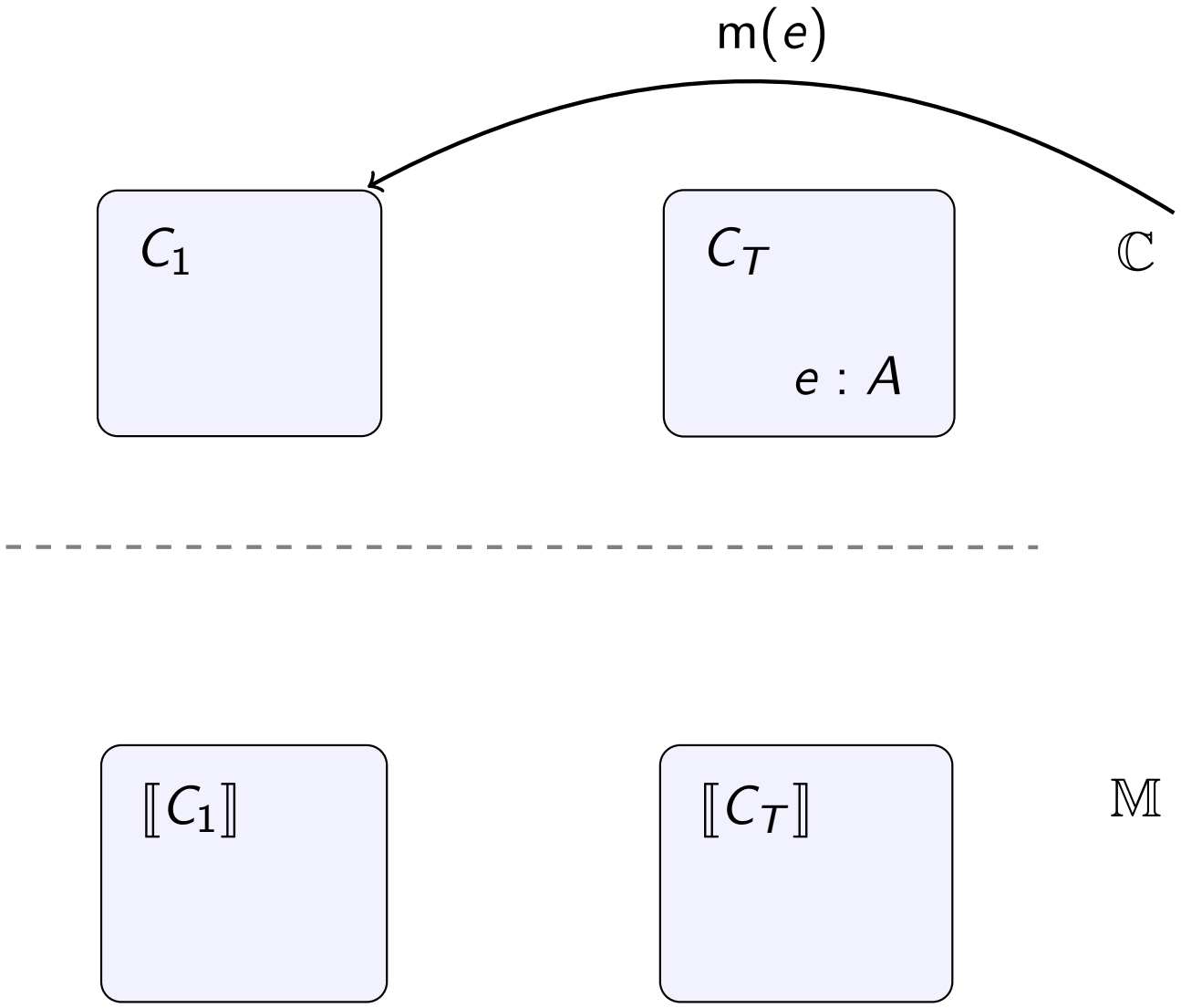


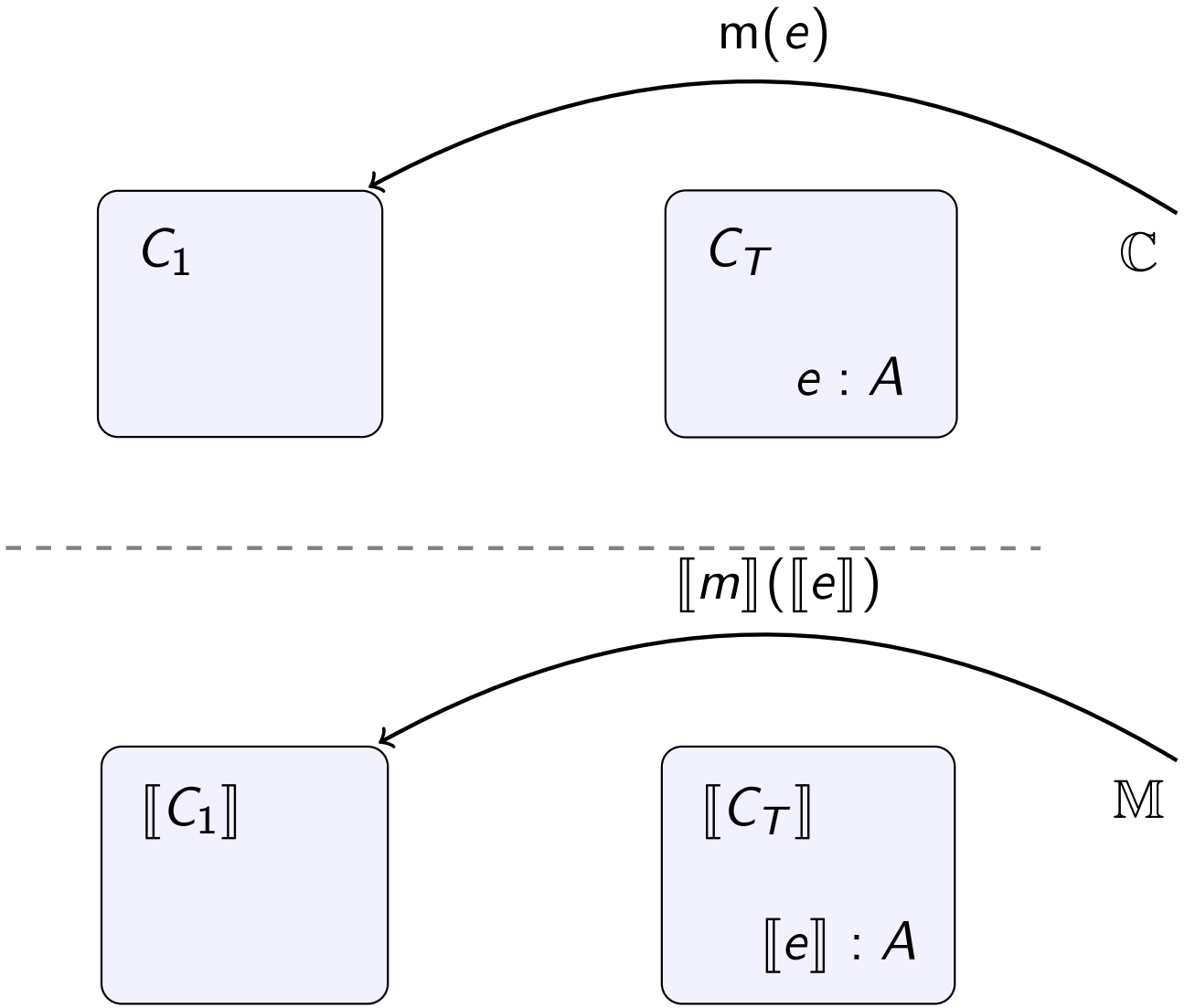
Addressing Object Guessing



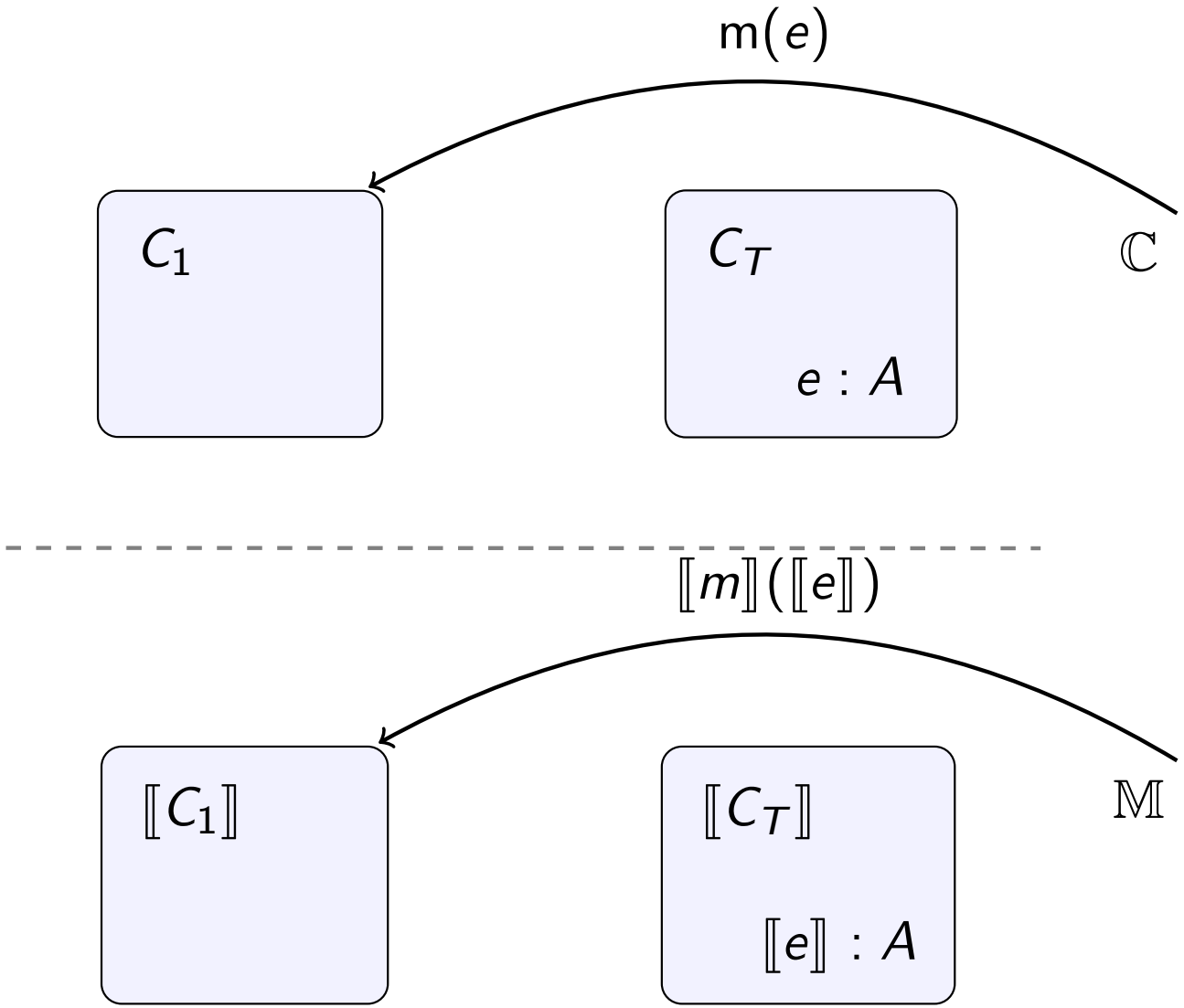
Addressing Object Faking



Addressing Object Faking

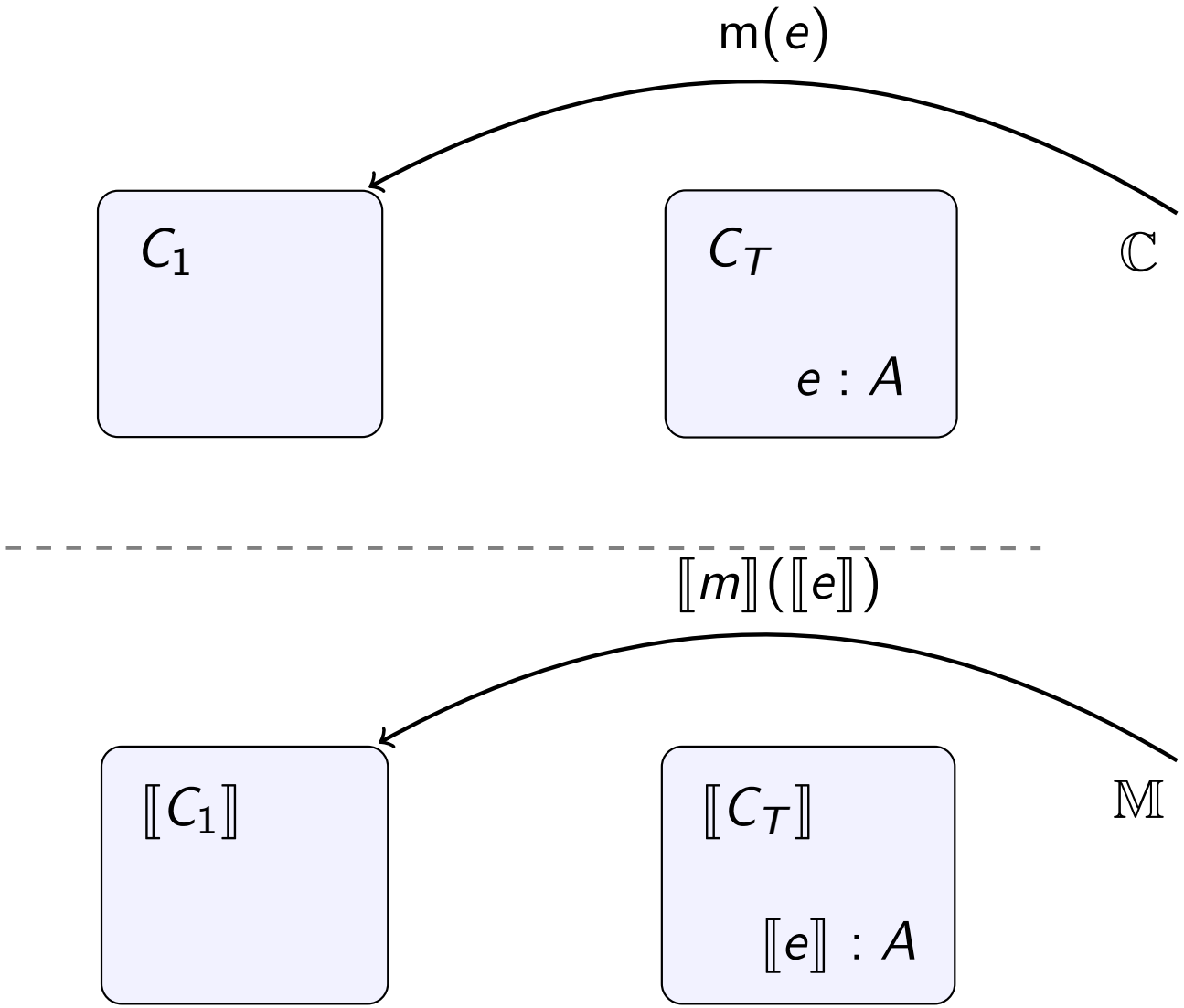


Addressing Object Faking



$[\![e]\!] = [\![\texttt{null}]\!]$
or obj : A

Addressing Object Faking



$[\![e]\!] = [\![\texttt{null}]\!]$
or obj : A
or obj : $B \not<: A$
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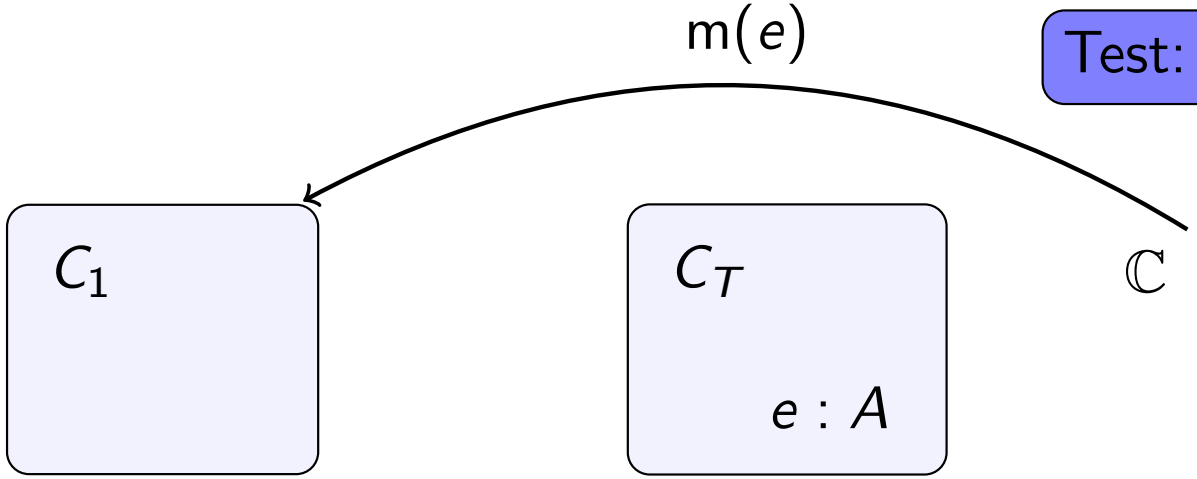
Addressing Object Faking



Test: Type & Existence

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or obj : $B \not<: A$
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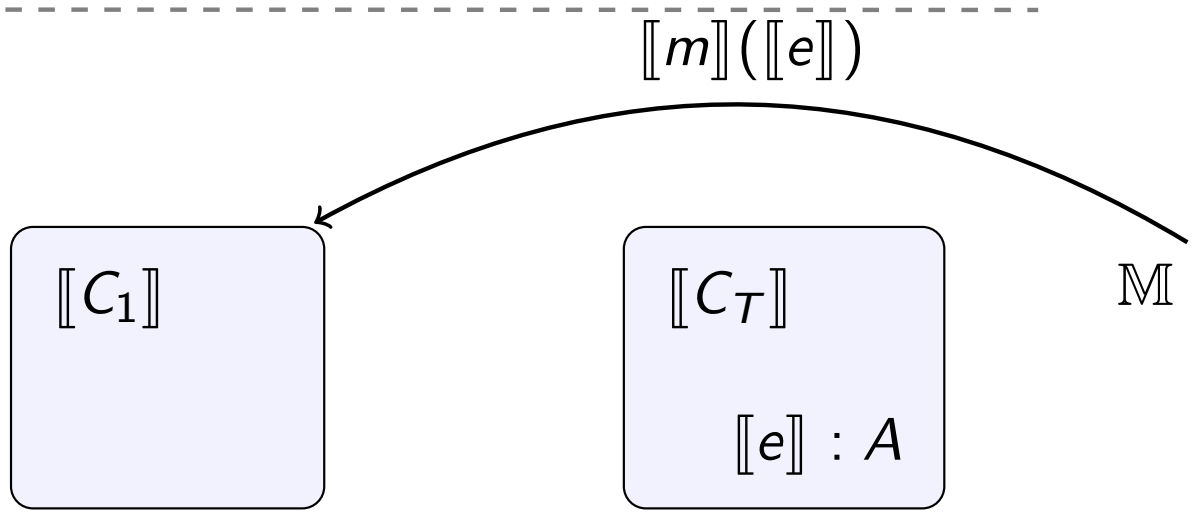

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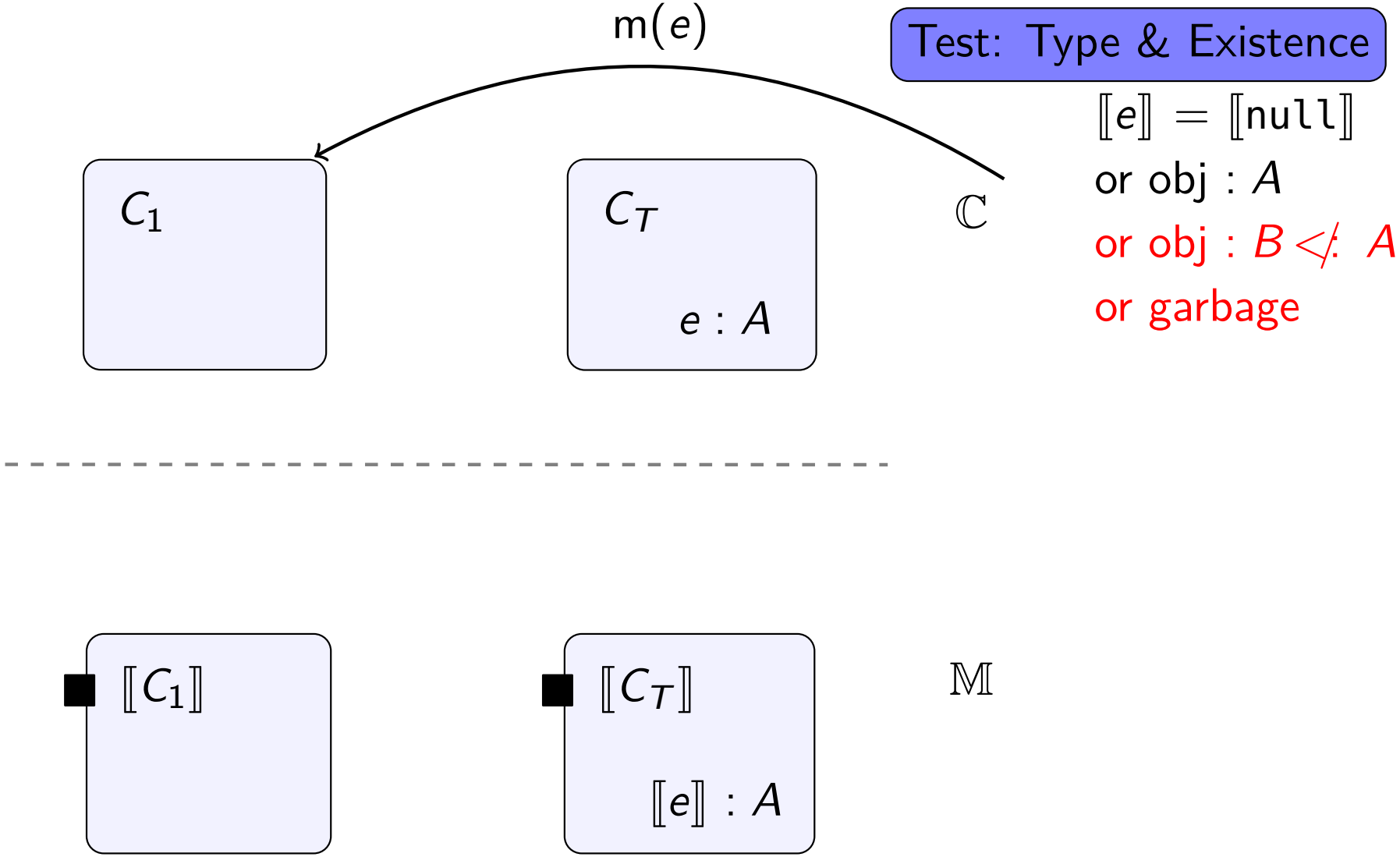

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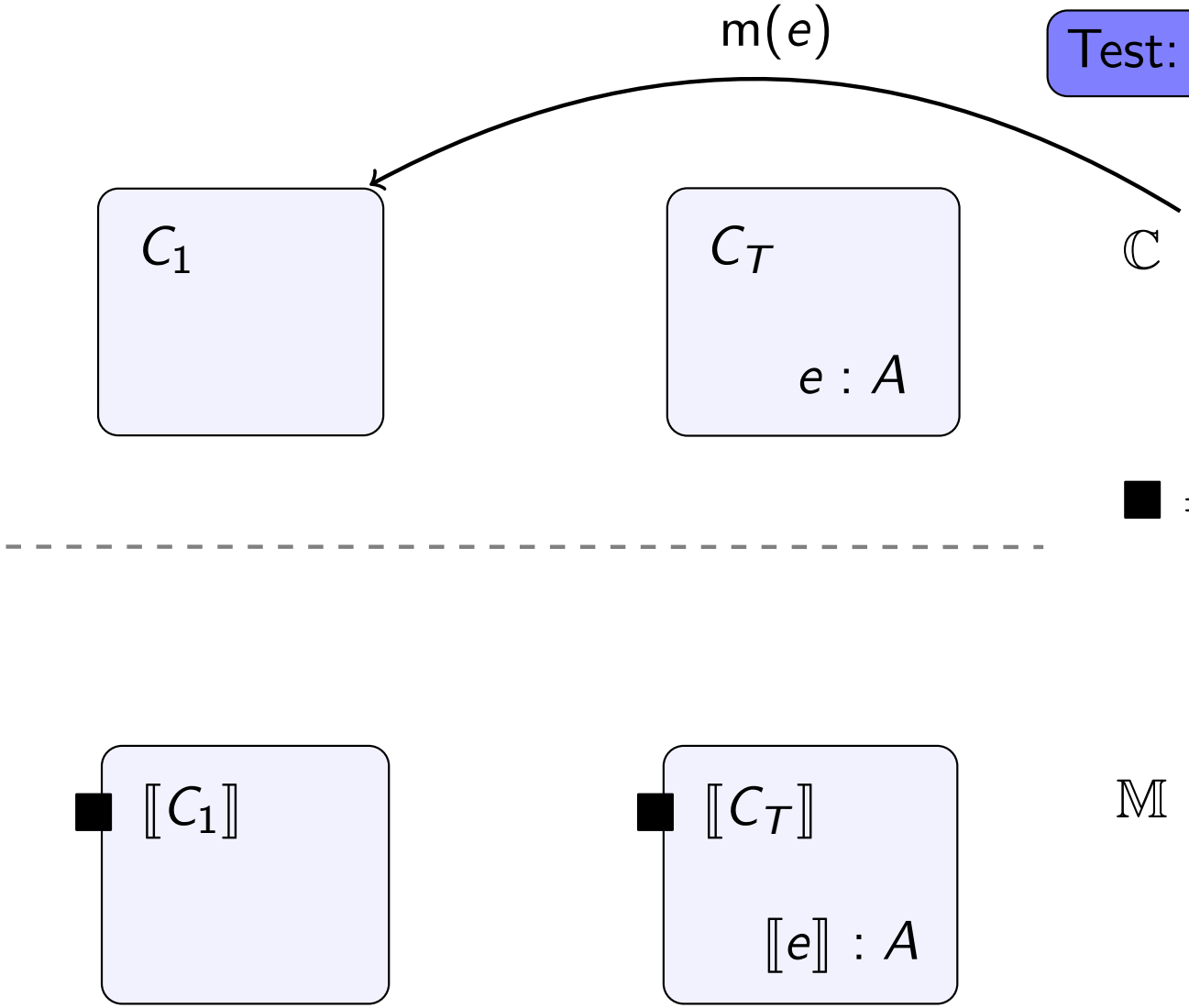

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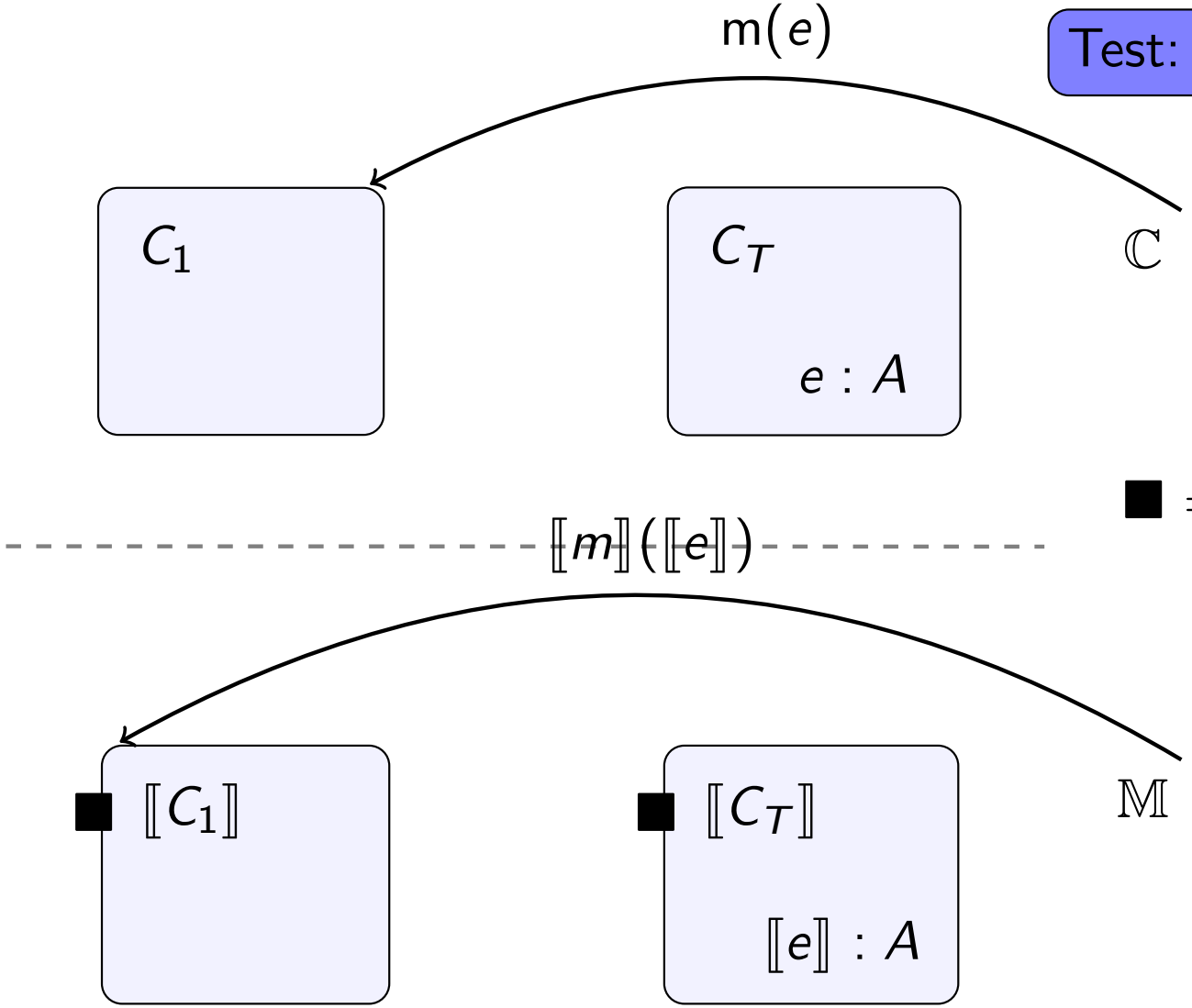
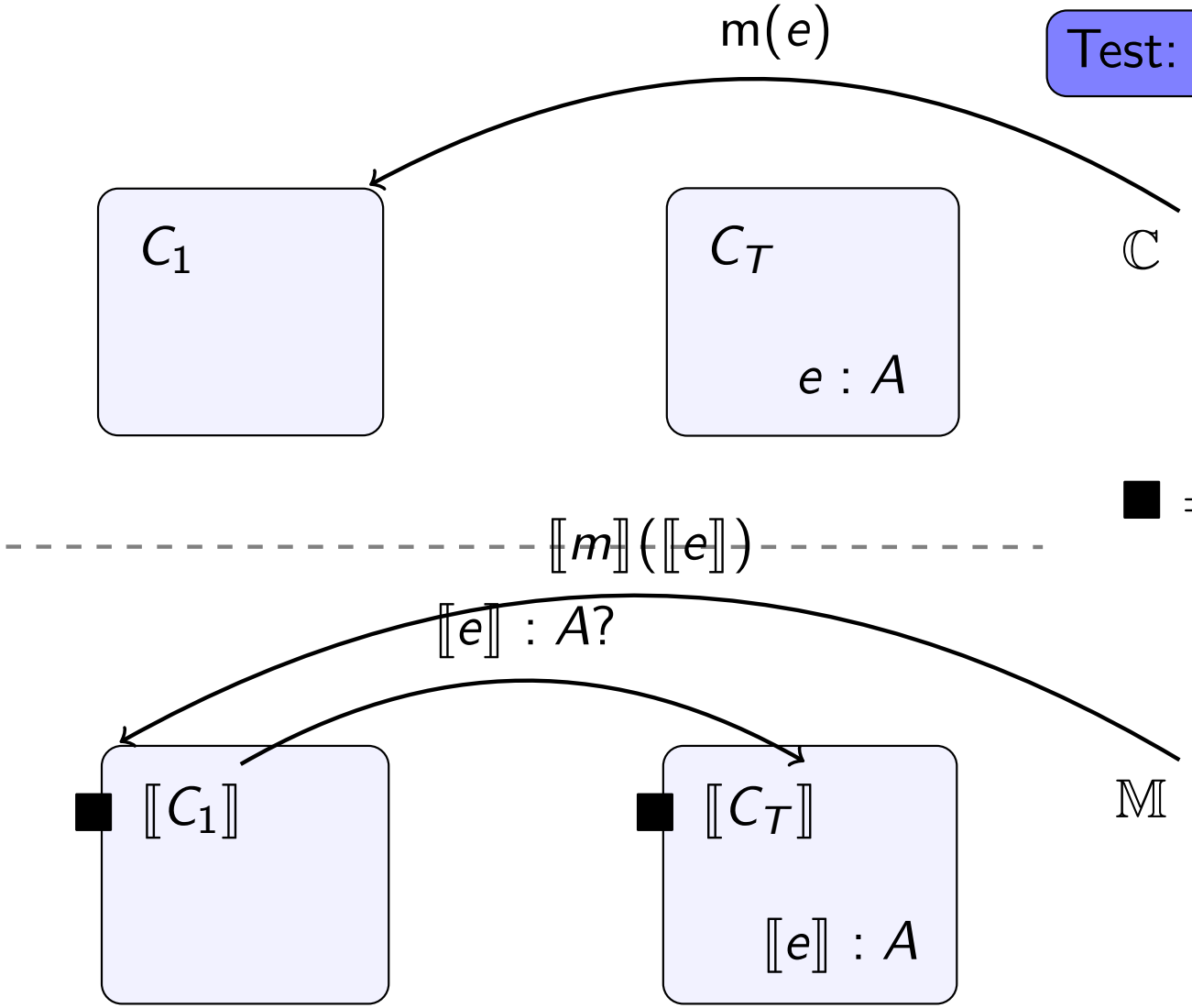


Test: Type & Existence

$[\![e]\!] = [\![\texttt{null}]\!]$
or obj : A
or obj : $B \not<: A$
or garbage

■ = $\texttt{instanceof}(o, A)$
$\hookrightarrow \texttt{0}$ if $o : A \in C_i$
$\hookrightarrow \texttt{1}$ if $o : B \in C_i$
$\hookrightarrow \texttt{1}$ if $o \notin C_i$

Addressing Object Faking



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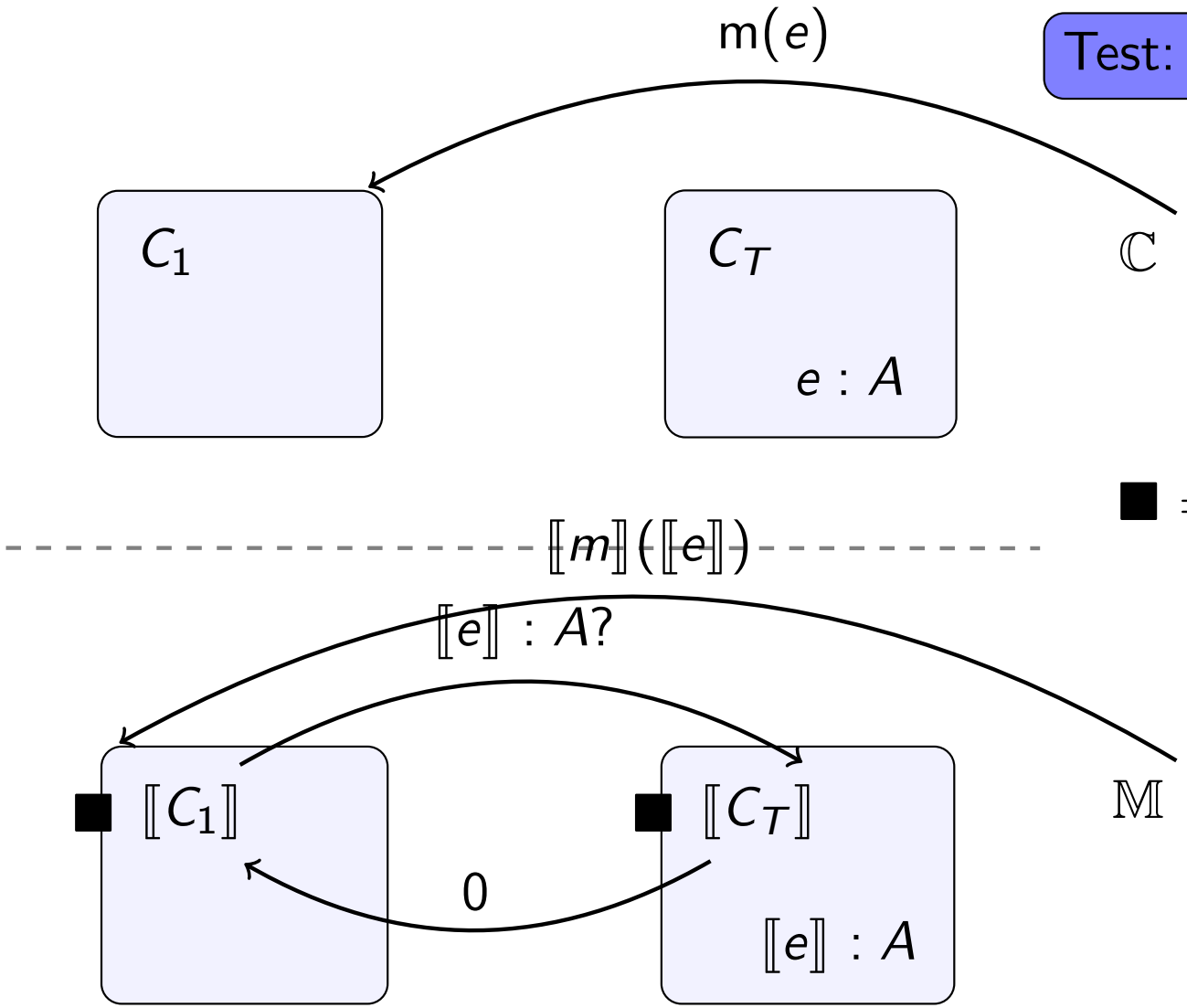

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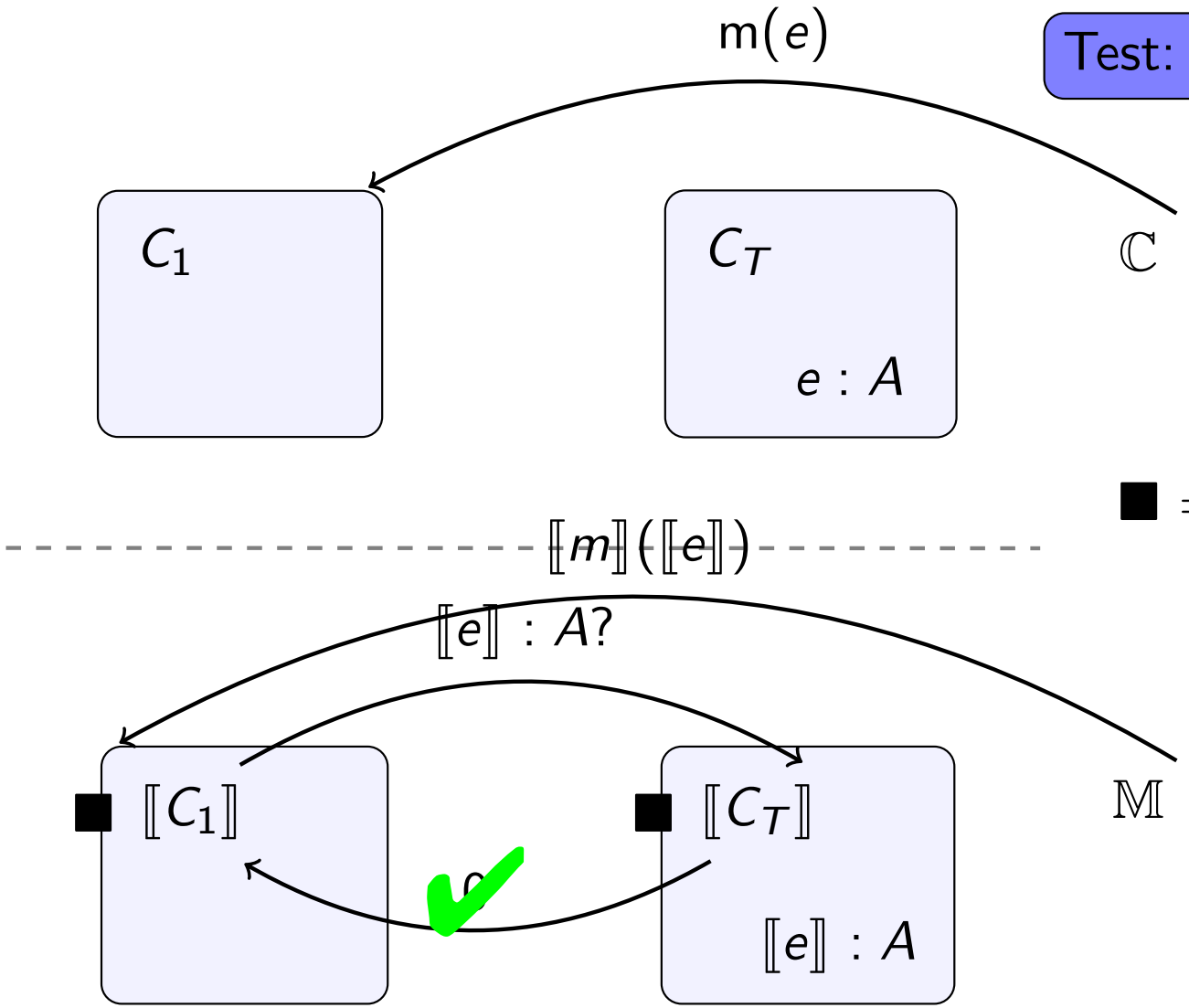

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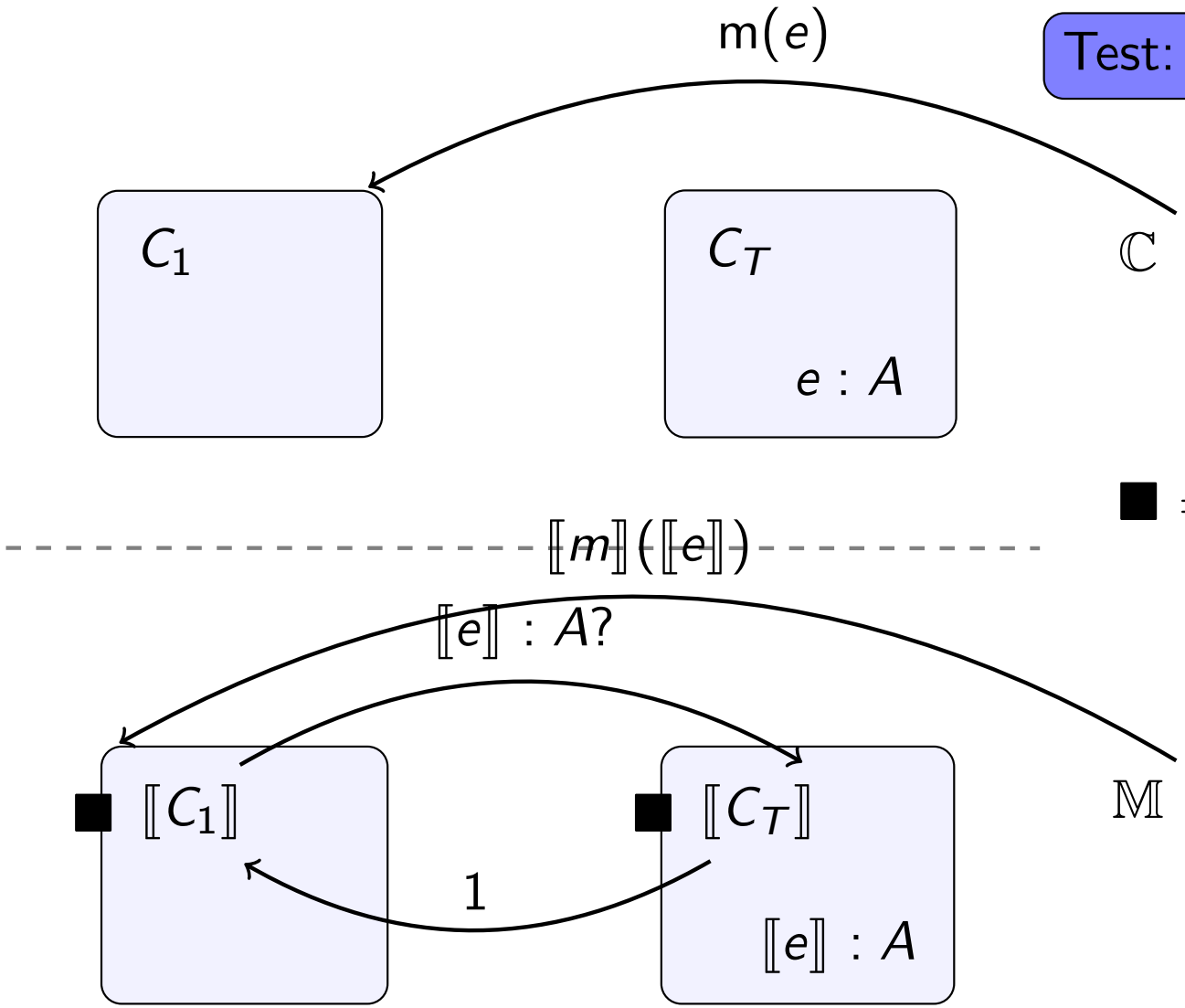

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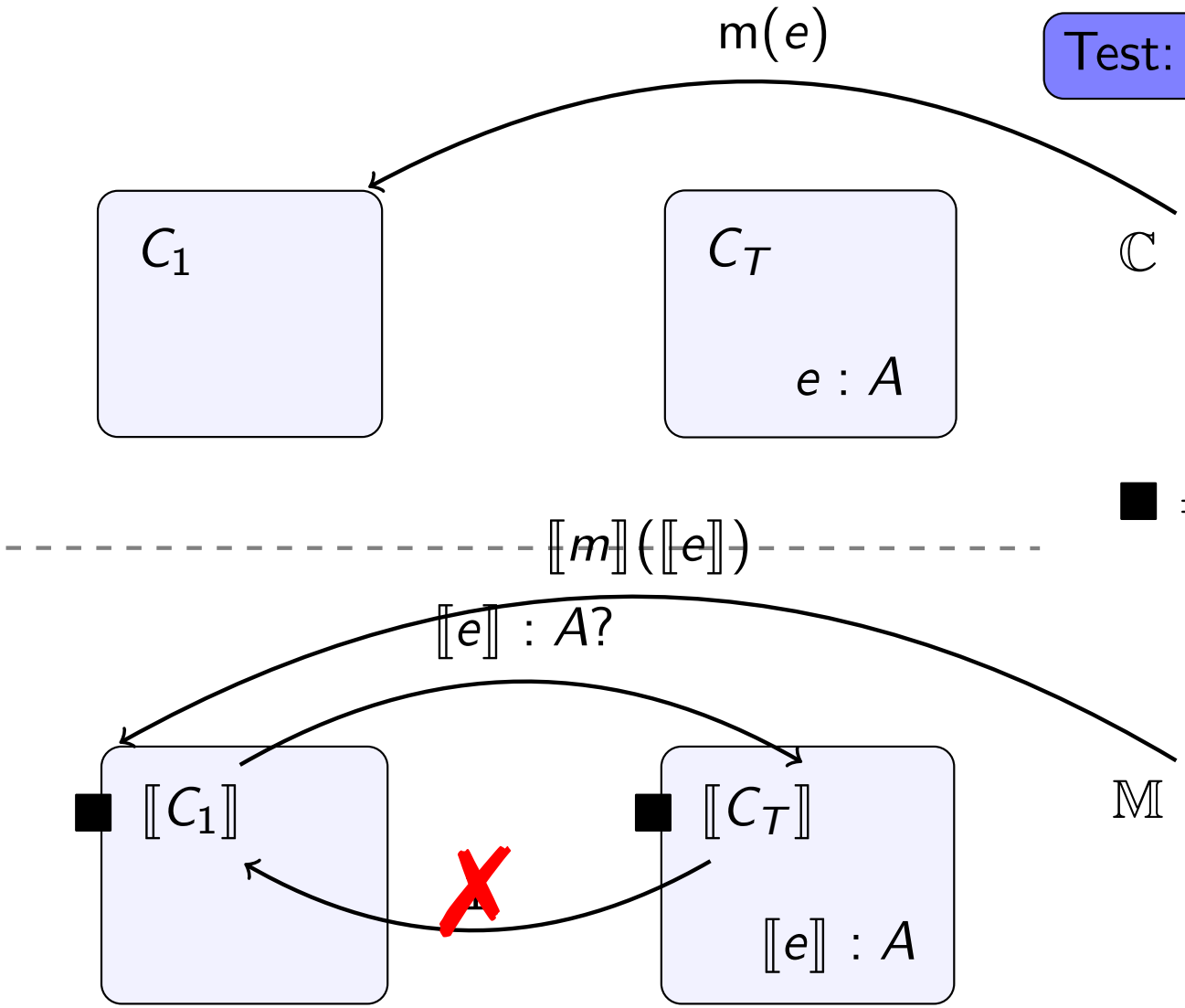

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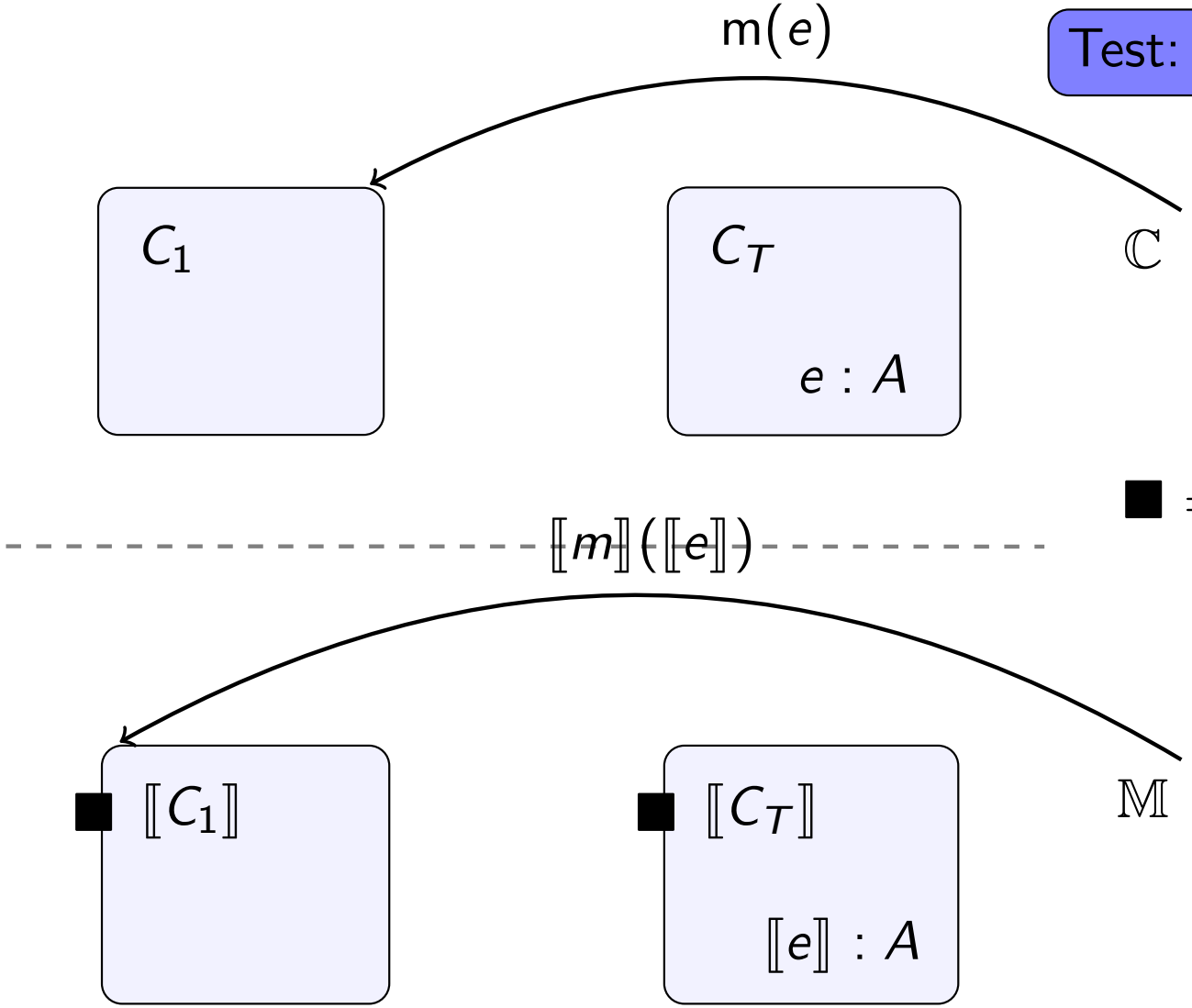

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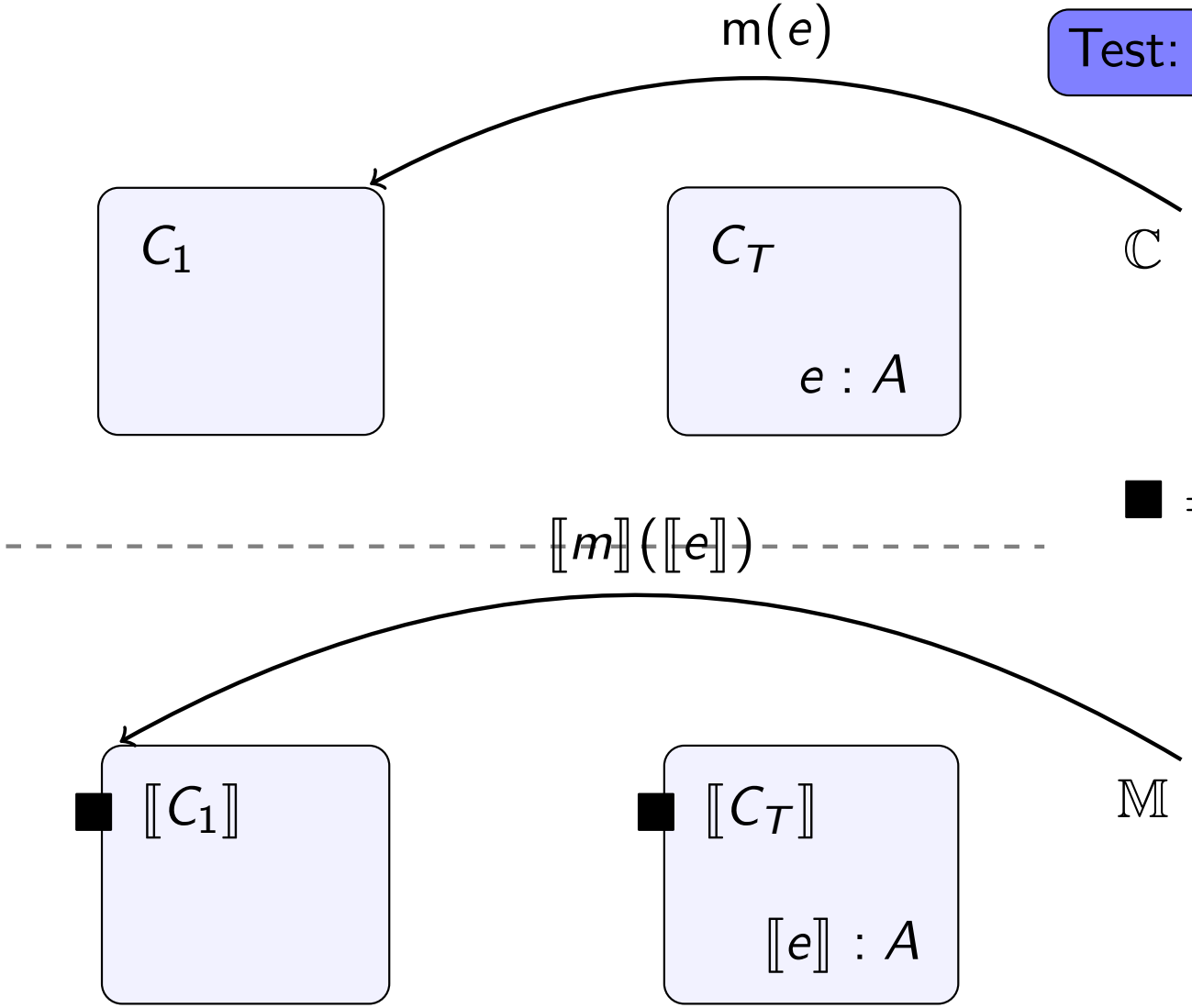
■ $\in \mathcal{S}$

Addressing Object Faking



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■ $\in \mathcal{S}$

■ $\notin C_i$

Questions

Thank you!

Qs ?