Linked Lists

Part One

Outline for Today

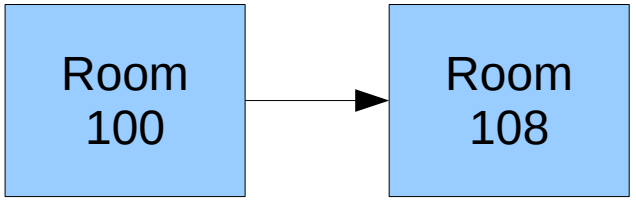
- ***Linked Lists, Conceptually***
  - A different way to represent a sequence.
- ***Linked Lists, In Code***
  - Some cool new C++ tricks.

Changing Offices

The Sign on Room 100

Dr. Cynthia Lee is no longer in room 100.

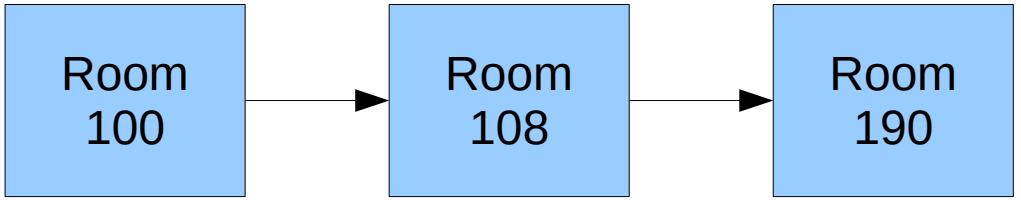
She can be found in room 108.



The Sign on Room 108

Dr. Cynthia Lee is no longer in room 108.

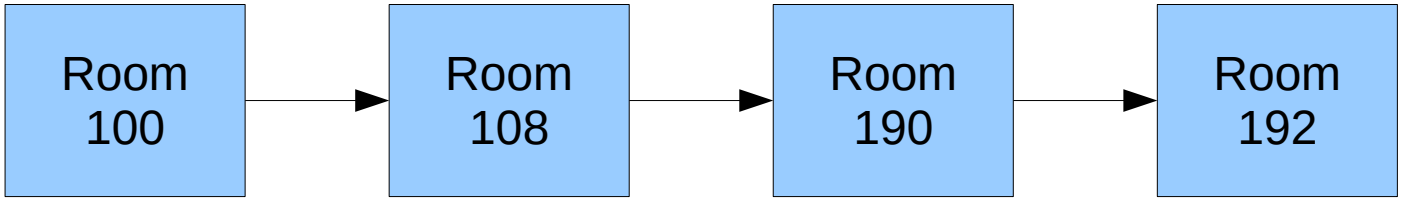
She can be found in room 190.



The Sign on Room 190

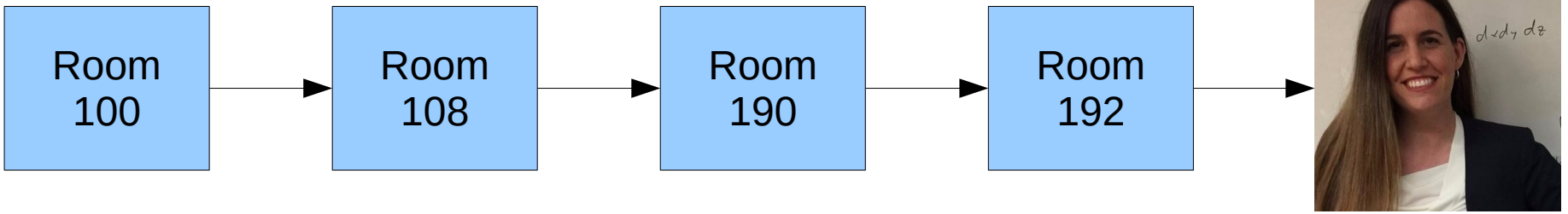
Dr. Cynthia Lee is no longer in room 190.

She can be found in room 192.



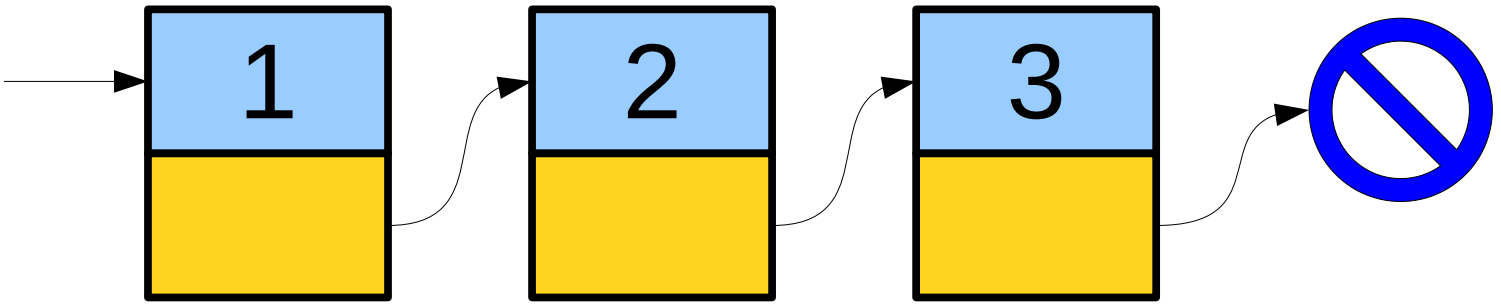
The Sign on Room 192

Welcome to Cynthia's Office!



Linked Lists at a Glance

- A ***linked list*** is a data structure for storing a sequence of elements.
- Each element is stored separately from the rest.
- The elements are then chained together into a sequence.
- The end of the list is marked with some special indicator.



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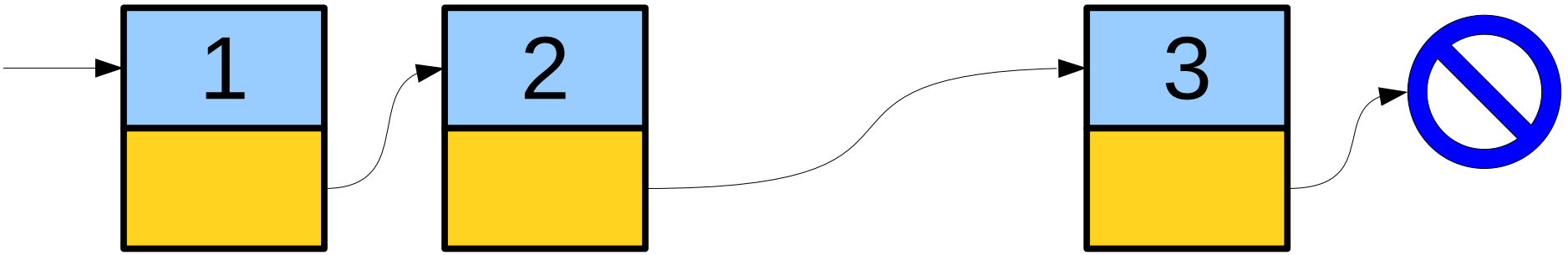

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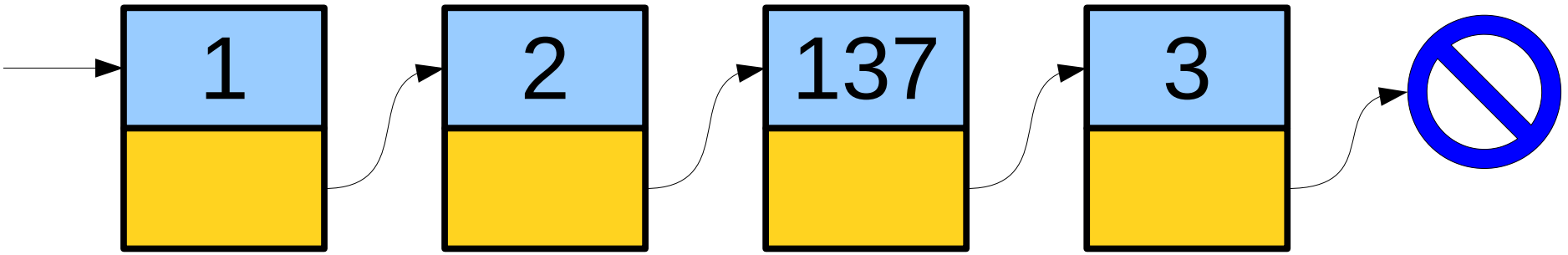

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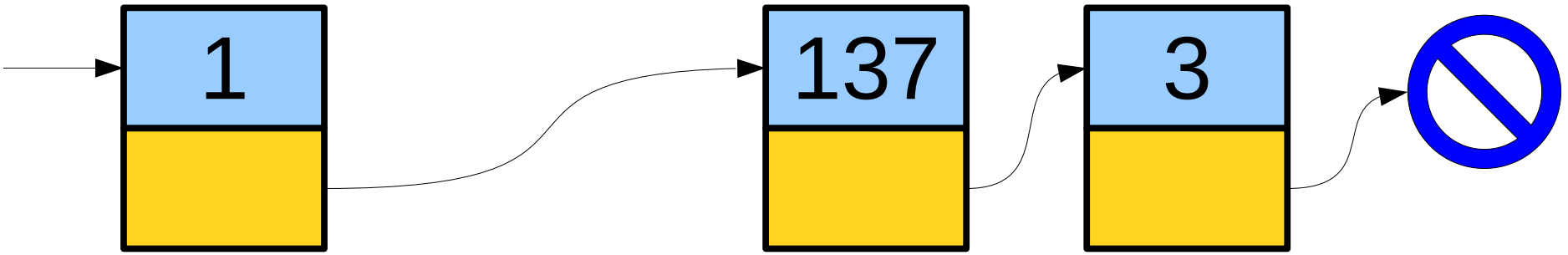
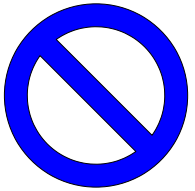
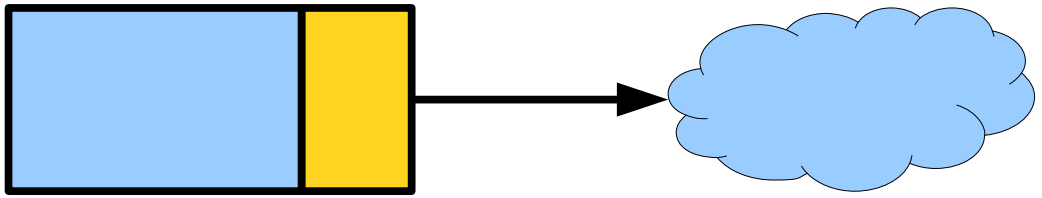


A Linked List is Either…

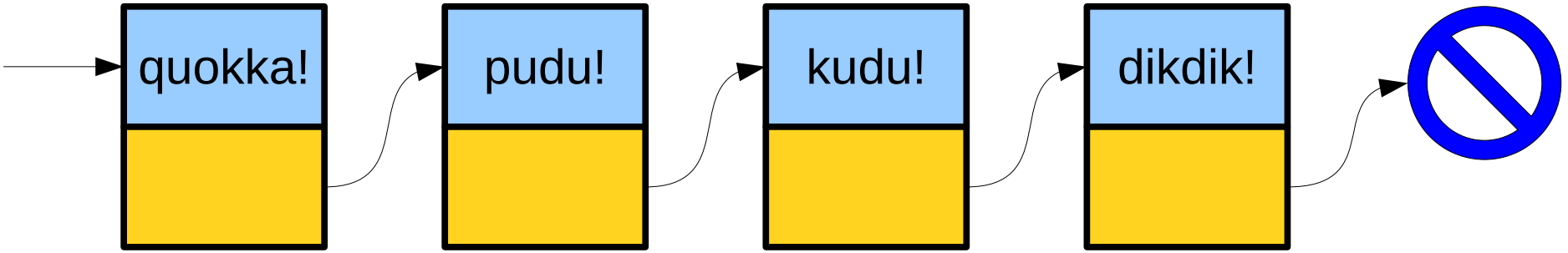
…an empty list,
or…





a single cell…

… that points at another linked list.



Representing Linked Lists

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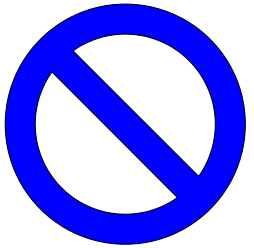

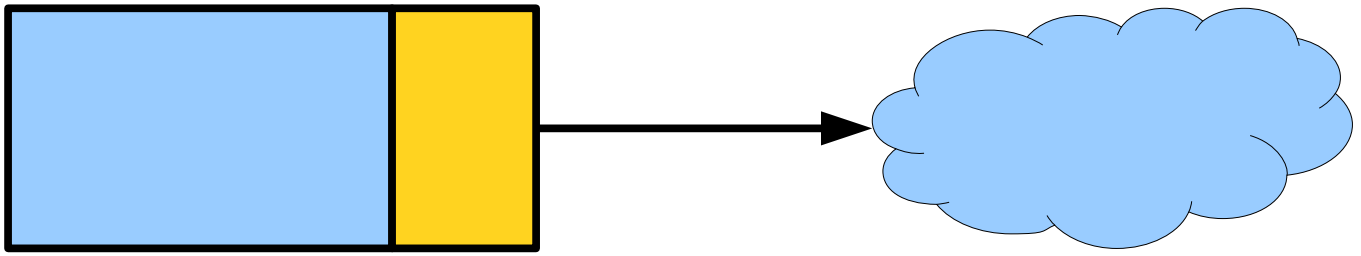

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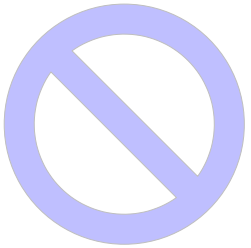

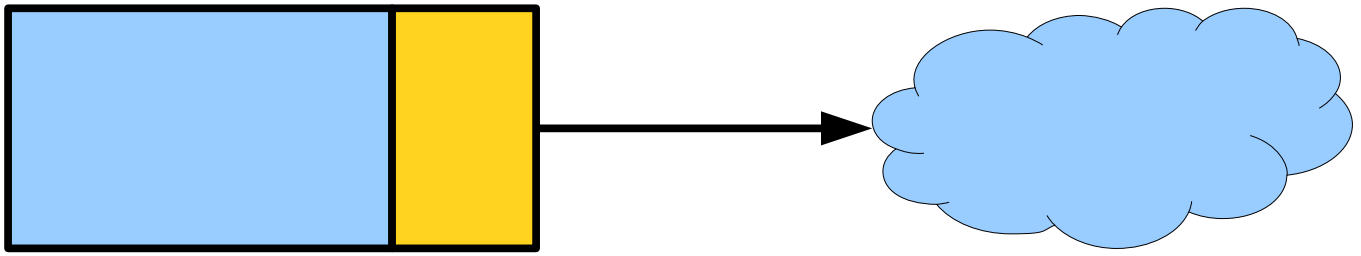

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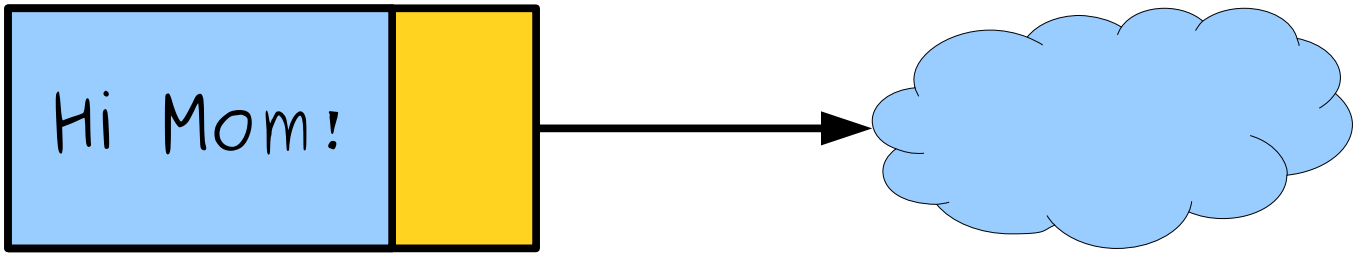
struct Cell {
    string value;
    Cell* next;
};
```



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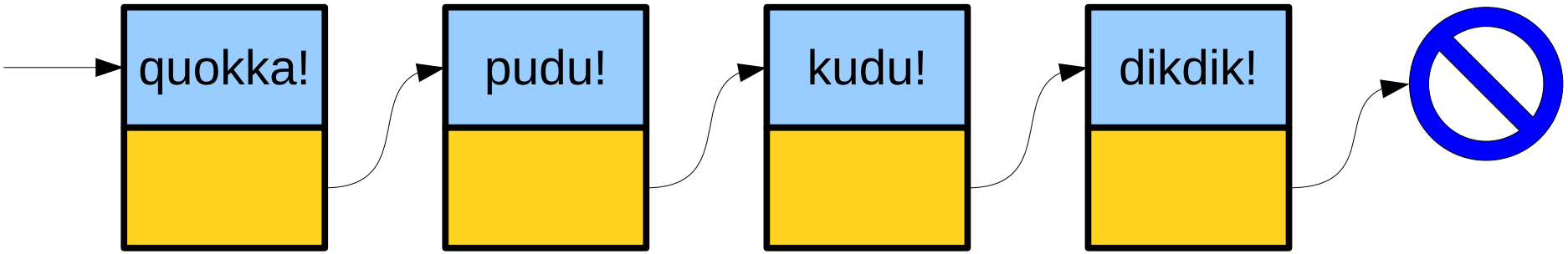
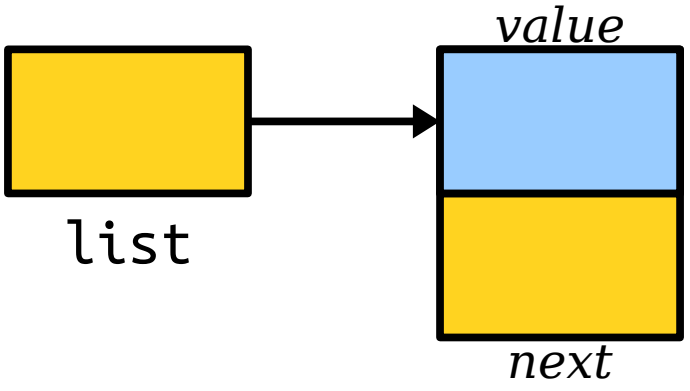


```
struct Cell {
    string value;
    Cell* next;
};

Cell* list = new Cell;
```

We just want a single cell, not an array of cells. To get the space we need, we'll just say `new Cell`.

Notice that `list` is still a `Cell*`, a pointer to a cell. It still says "look over there for your `Cell`" rather than "I'm a `Cell`!"



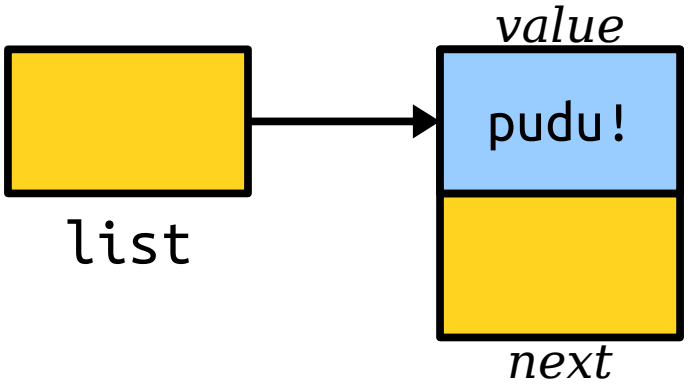
Yes, it's confusing that C++ uses the same types to mean "look over there for an array of `Cells`" and "look over there for a single `Cell`."

```
struct Cell {
    string value;
    Cell* next;
};

Cell* list = new Cell;
list->value = "pudu!";
```

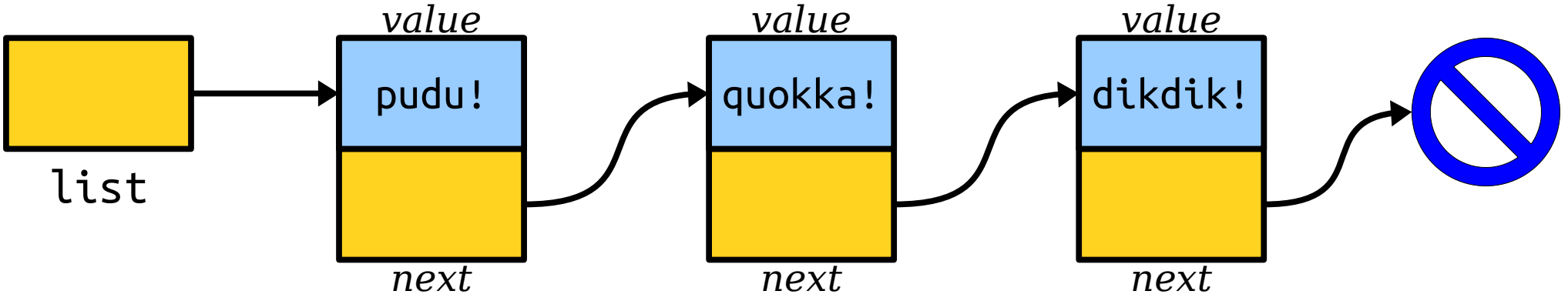
Because list is a pointer to a `Cell`, we use the arrow operator `->` instead of the dot operator.

Think of `list->value` as saying “start at `list`, follow an arrow, then pick the `value` field.”



```
struct Cell {
    string value;
    Cell* next;
};

Cell* list = new Cell;
list->value = "pudu!";
list->next = new Cell;
list->next->value = "quokka!";
list->next->next = new Cell;
list->next->next->value = "dikdik!";
list->next->next->next = nullptr;
```



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list->next->next->next = nullptr;
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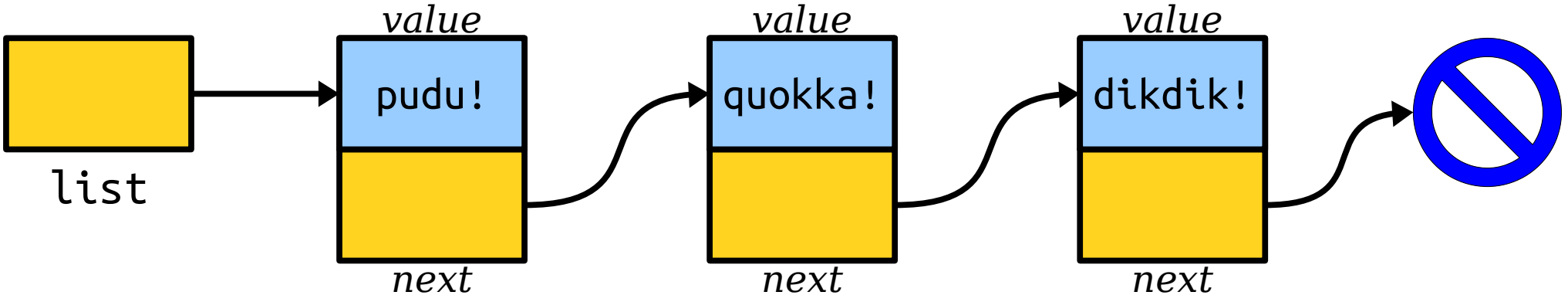
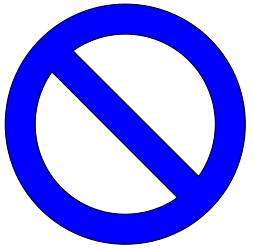
C++ uses the **nullptr** keyword to mean "a pointer that doesn't point at anything."

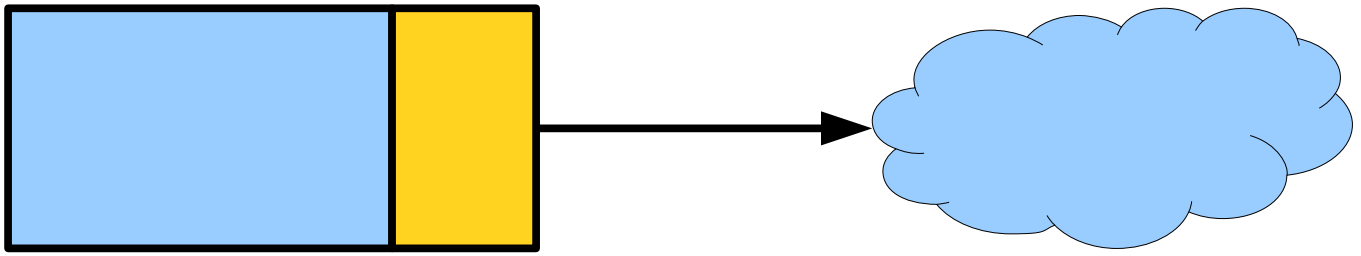
(Older code uses NULL instead of **nullptr**; that's also okay, but we recommend **nullptr**.)



A Linked List is Either…

…an empty list, represented by `nullptr`, or…





a single linked list cell that points…

… at another linked list.

Measuring a Linked List

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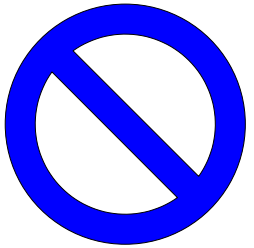

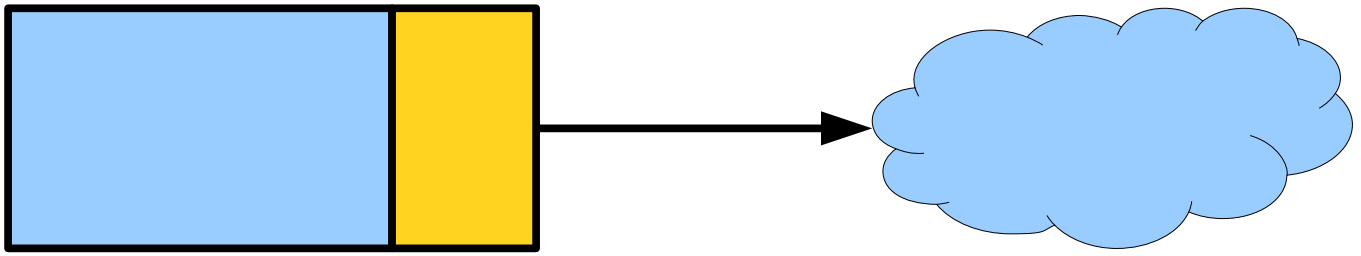

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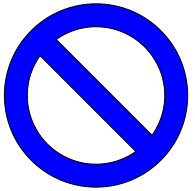

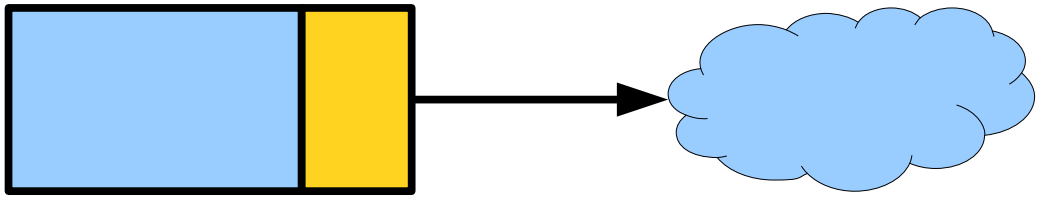

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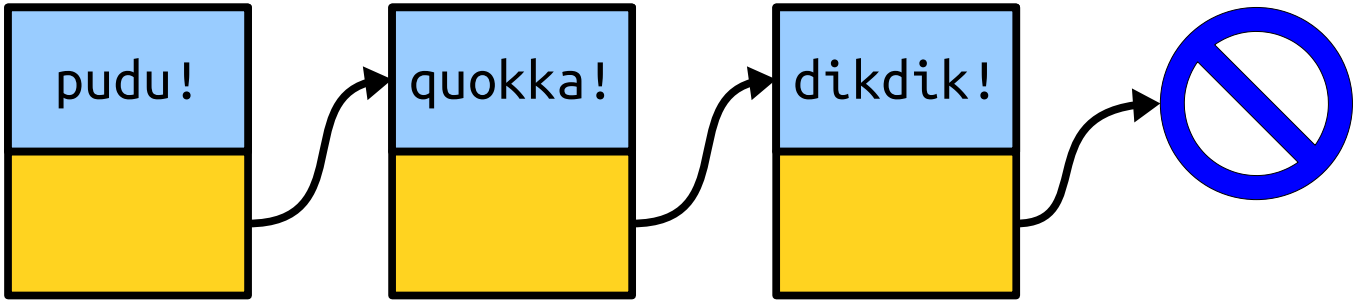

Printing a Linked List

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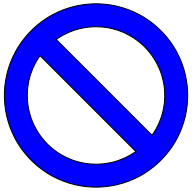

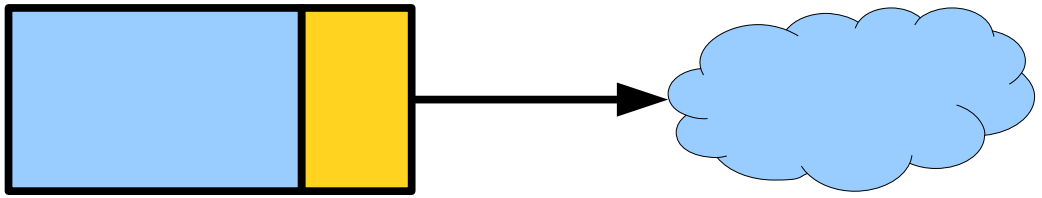

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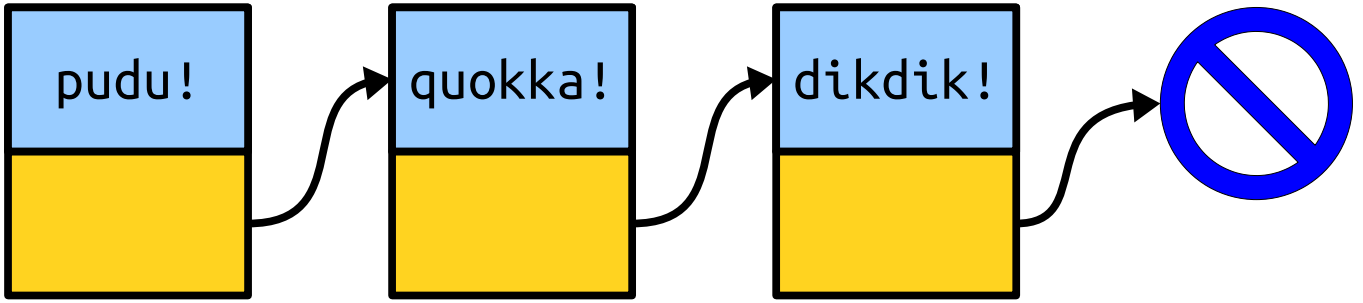

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    Cell* list = /* … a list … */;
    printList(list);

    /* … other listy things. … */
}
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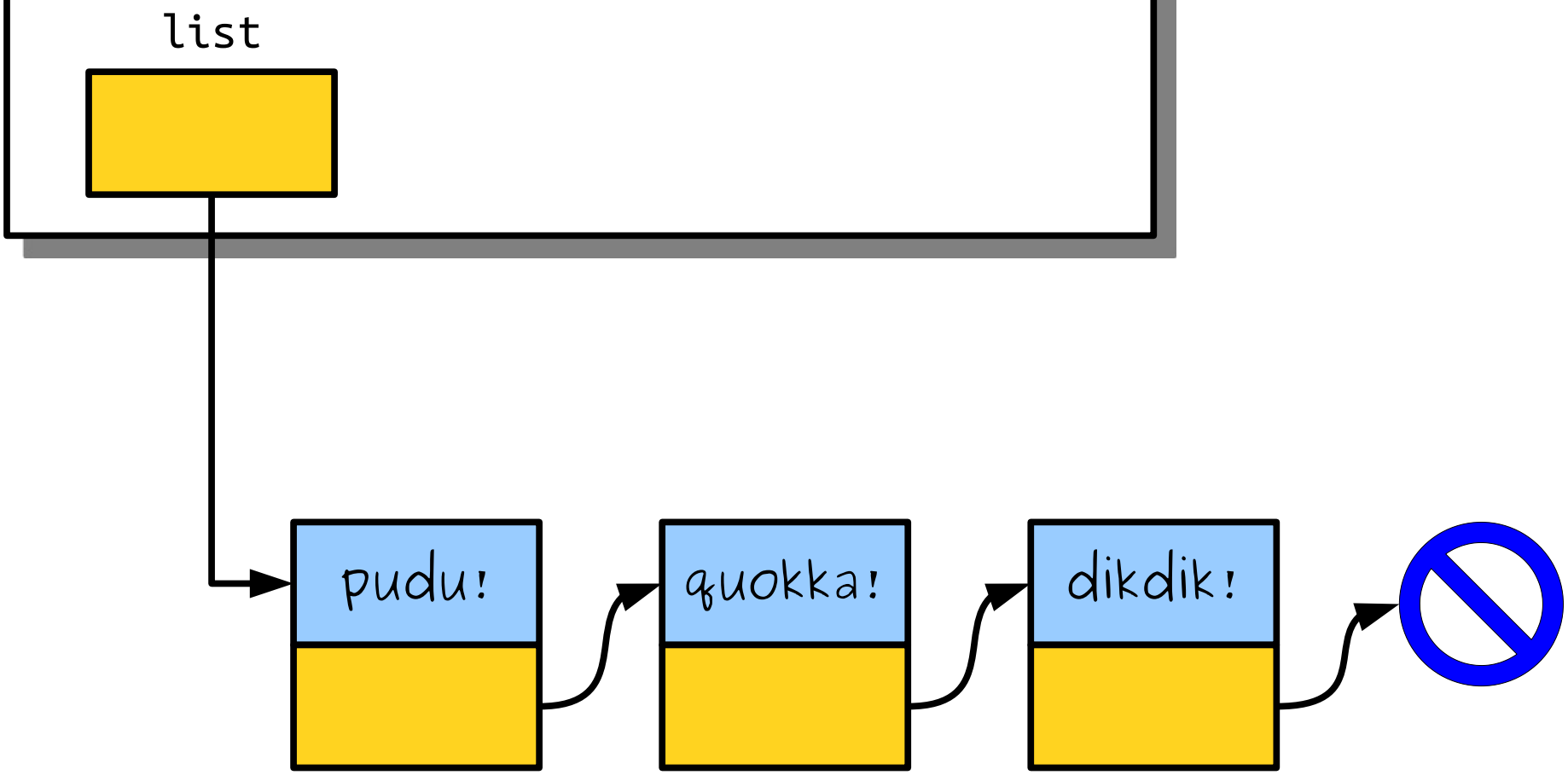

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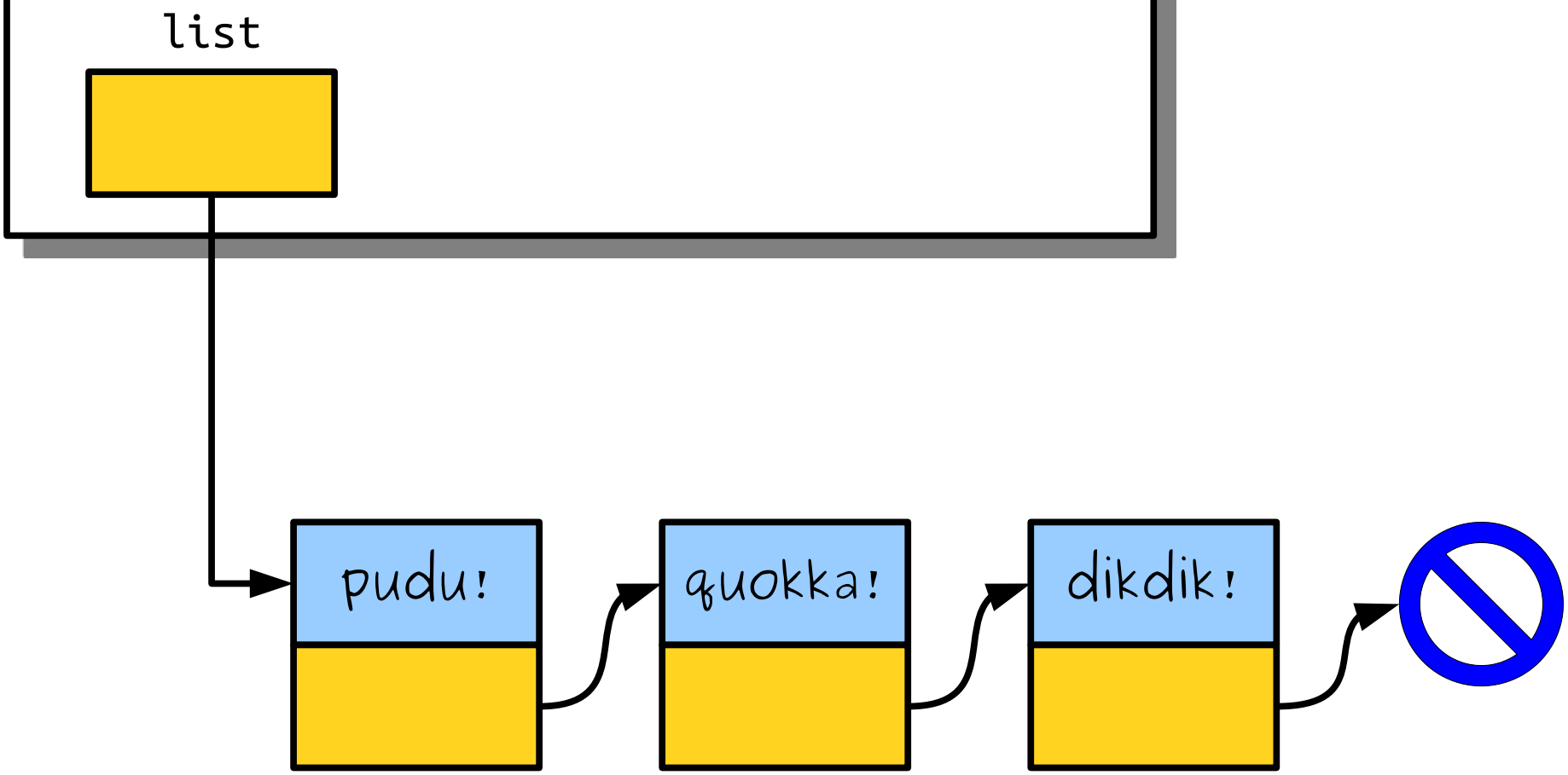

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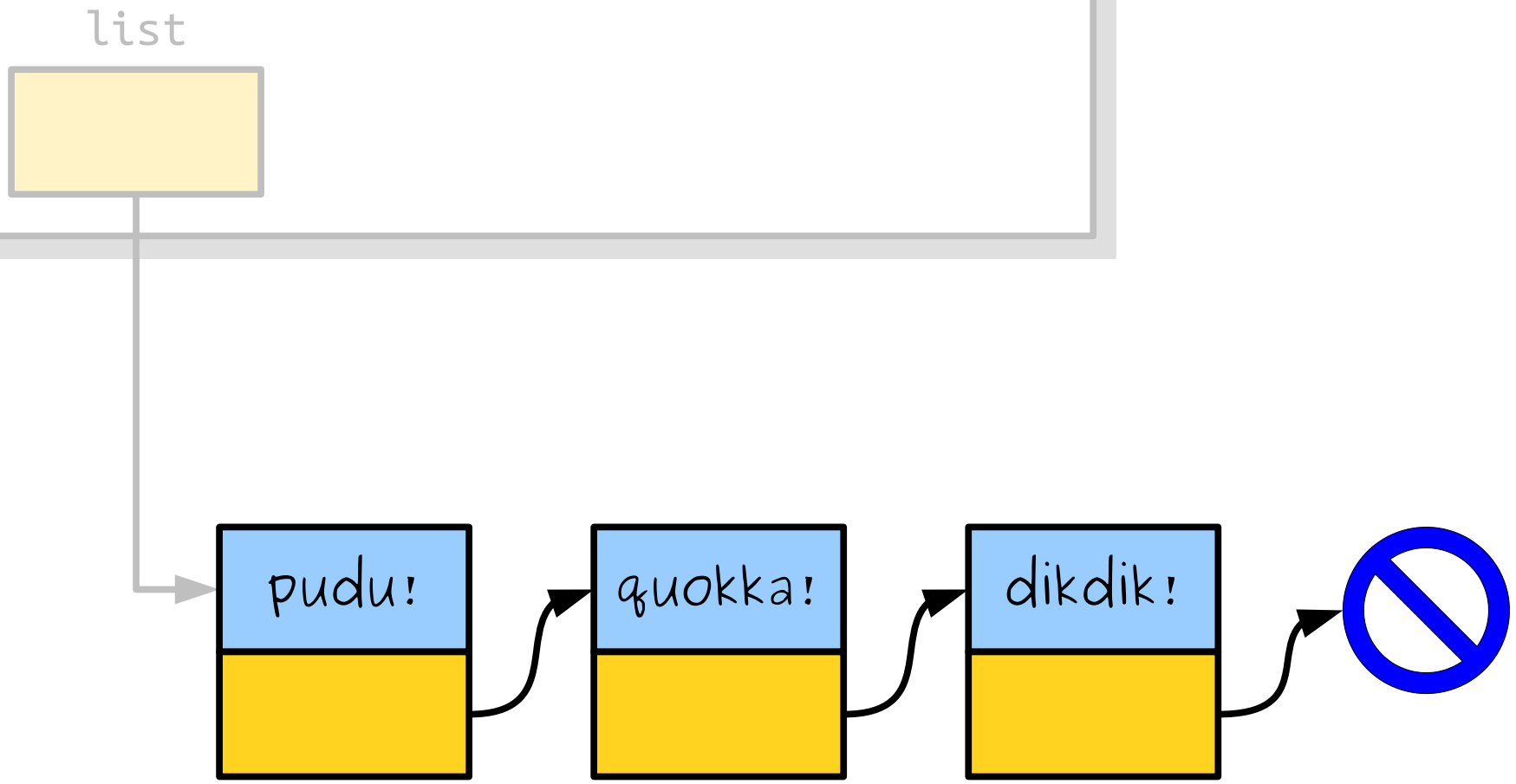

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void printList(Cell* list) {
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        cout << list->value << endl;
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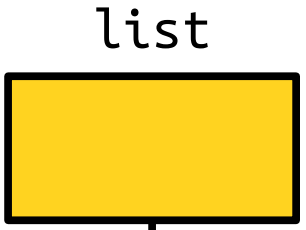

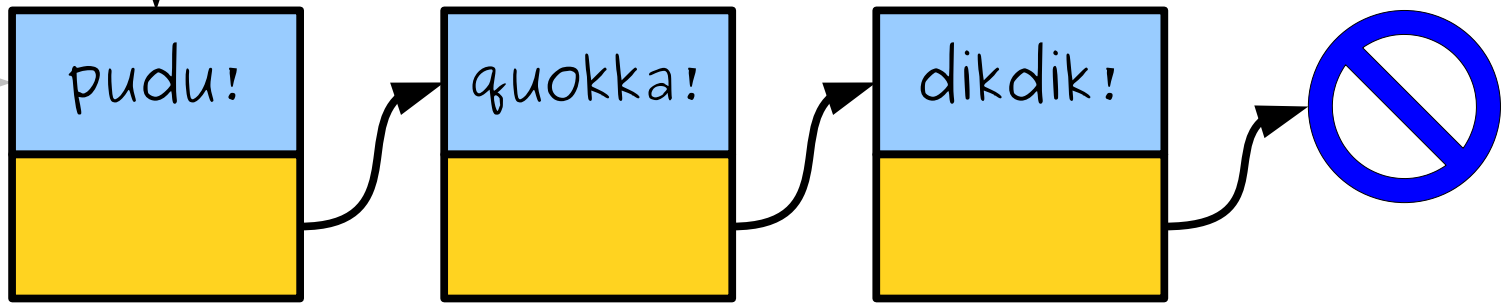

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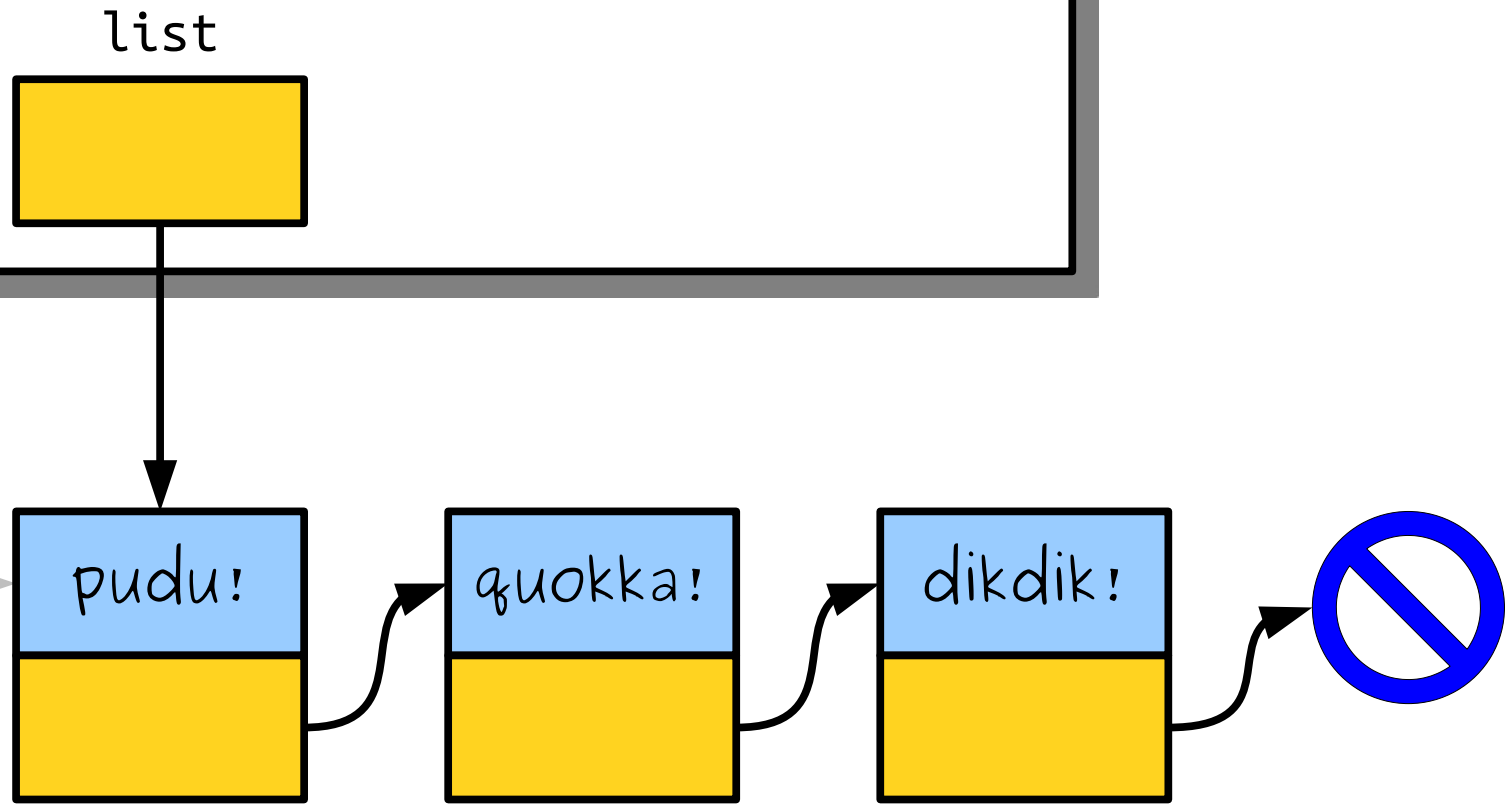

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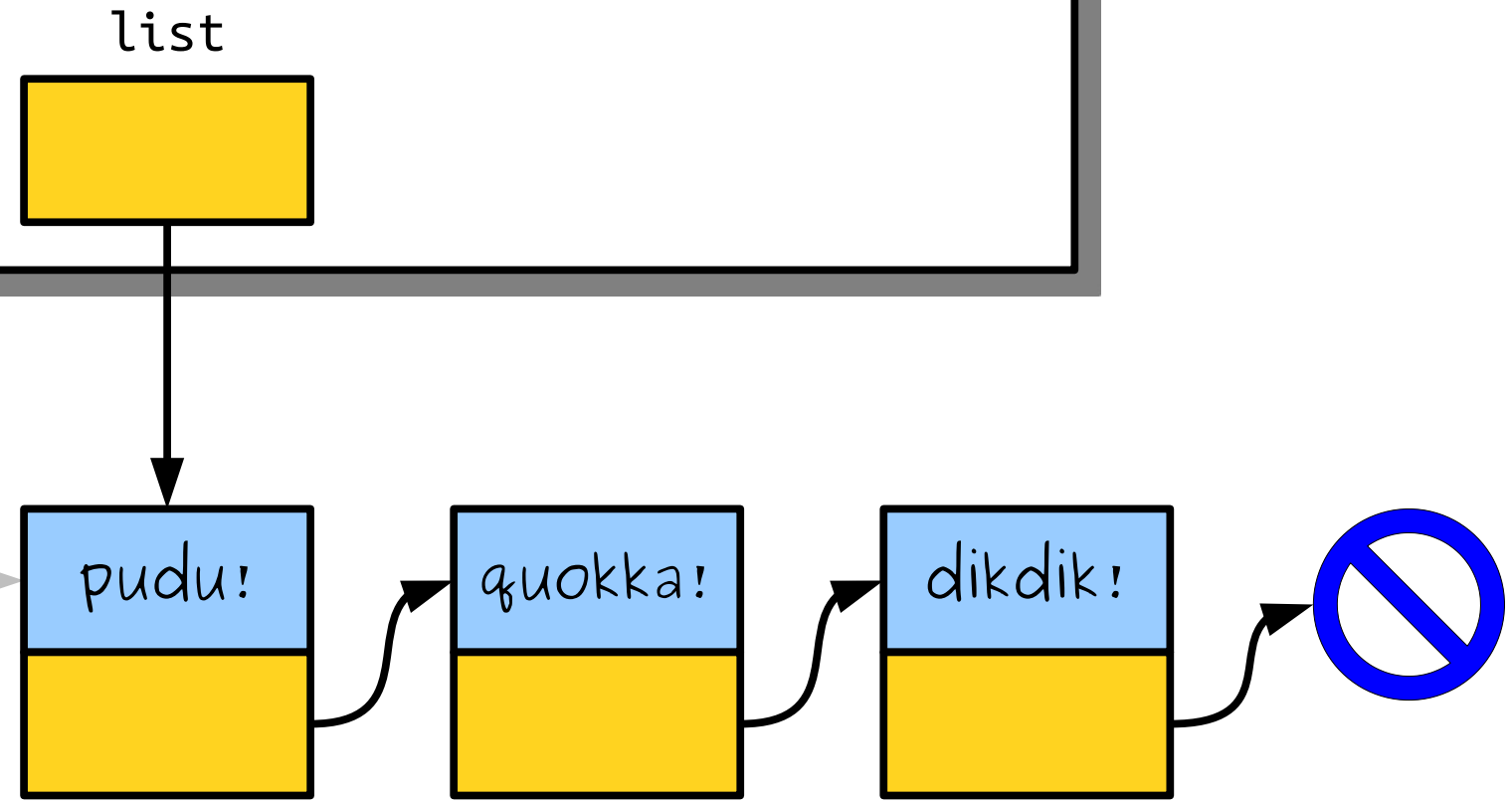

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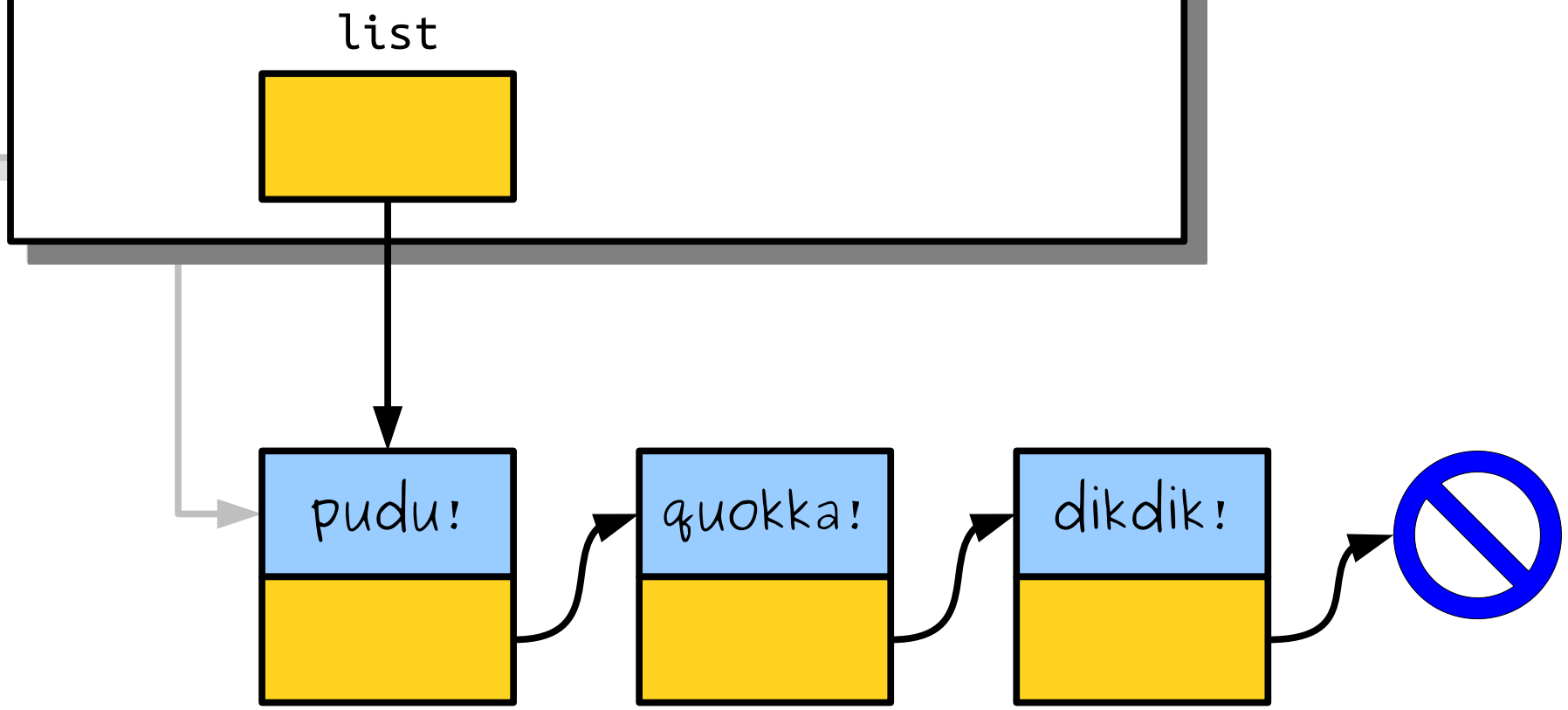

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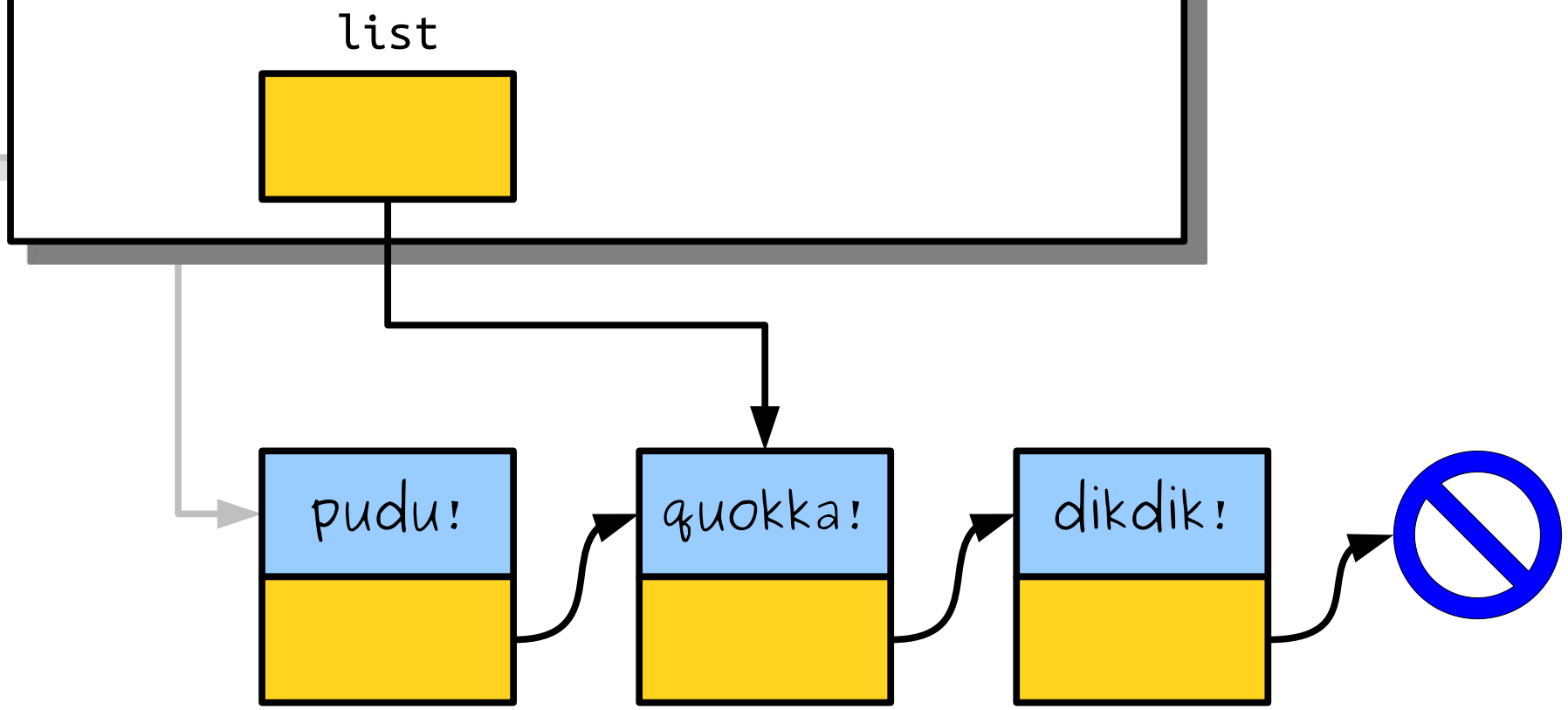

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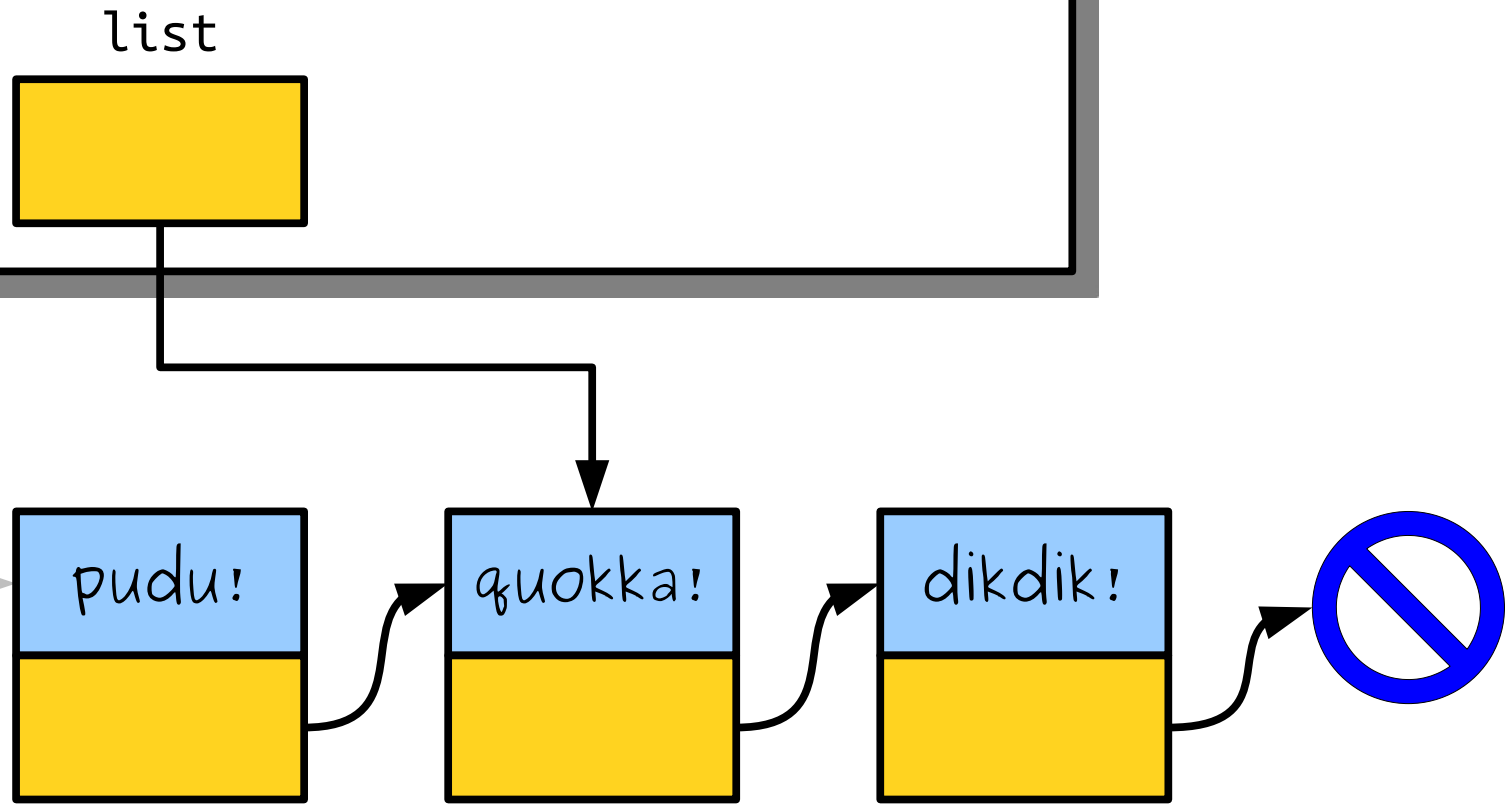

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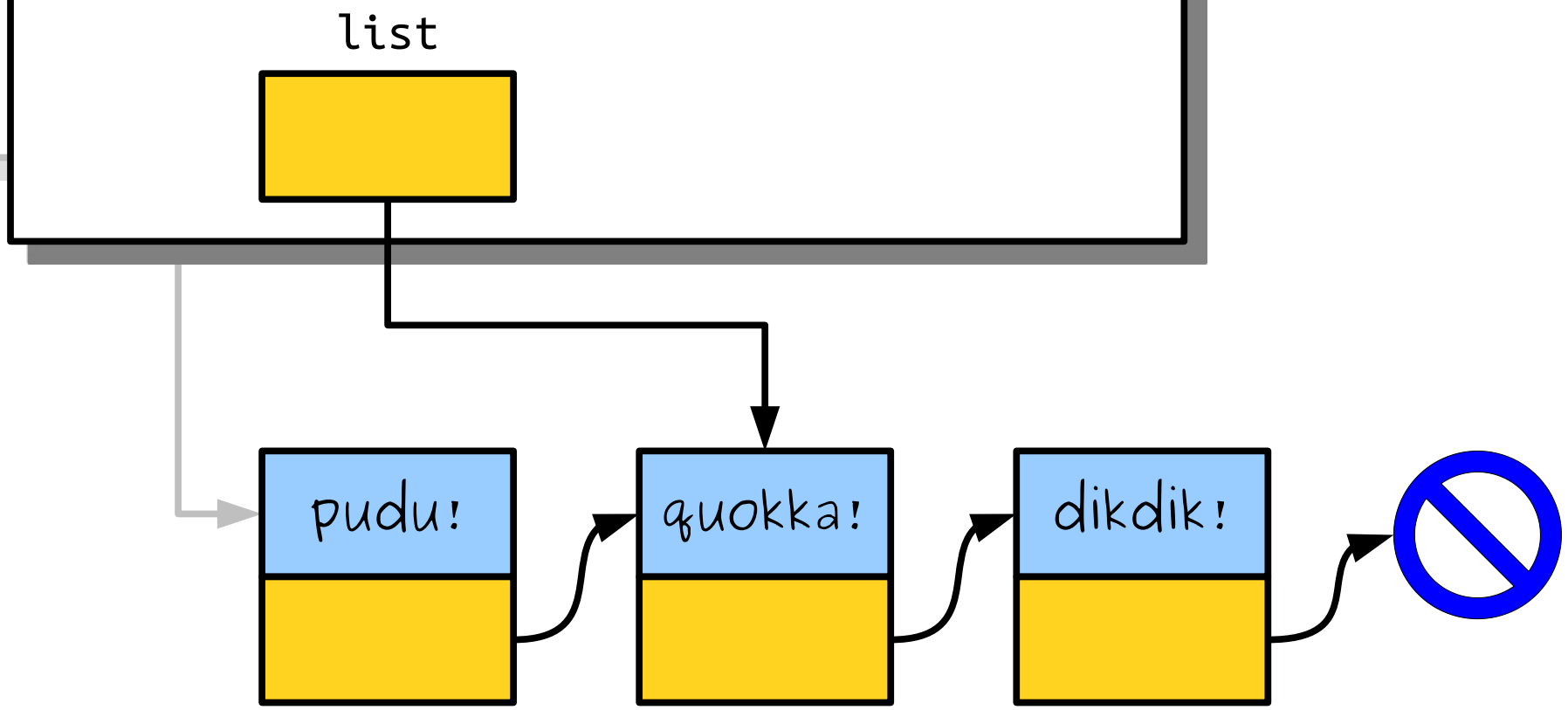

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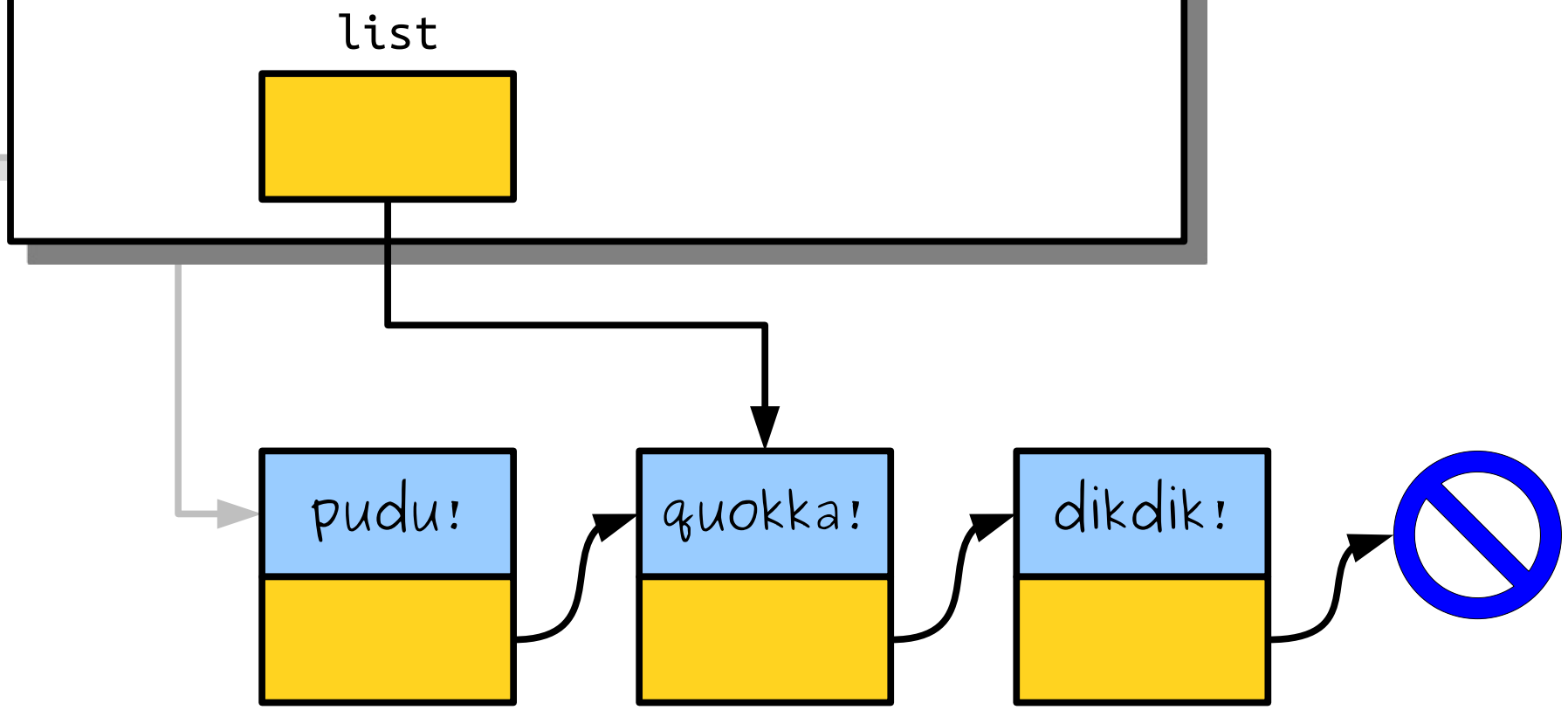

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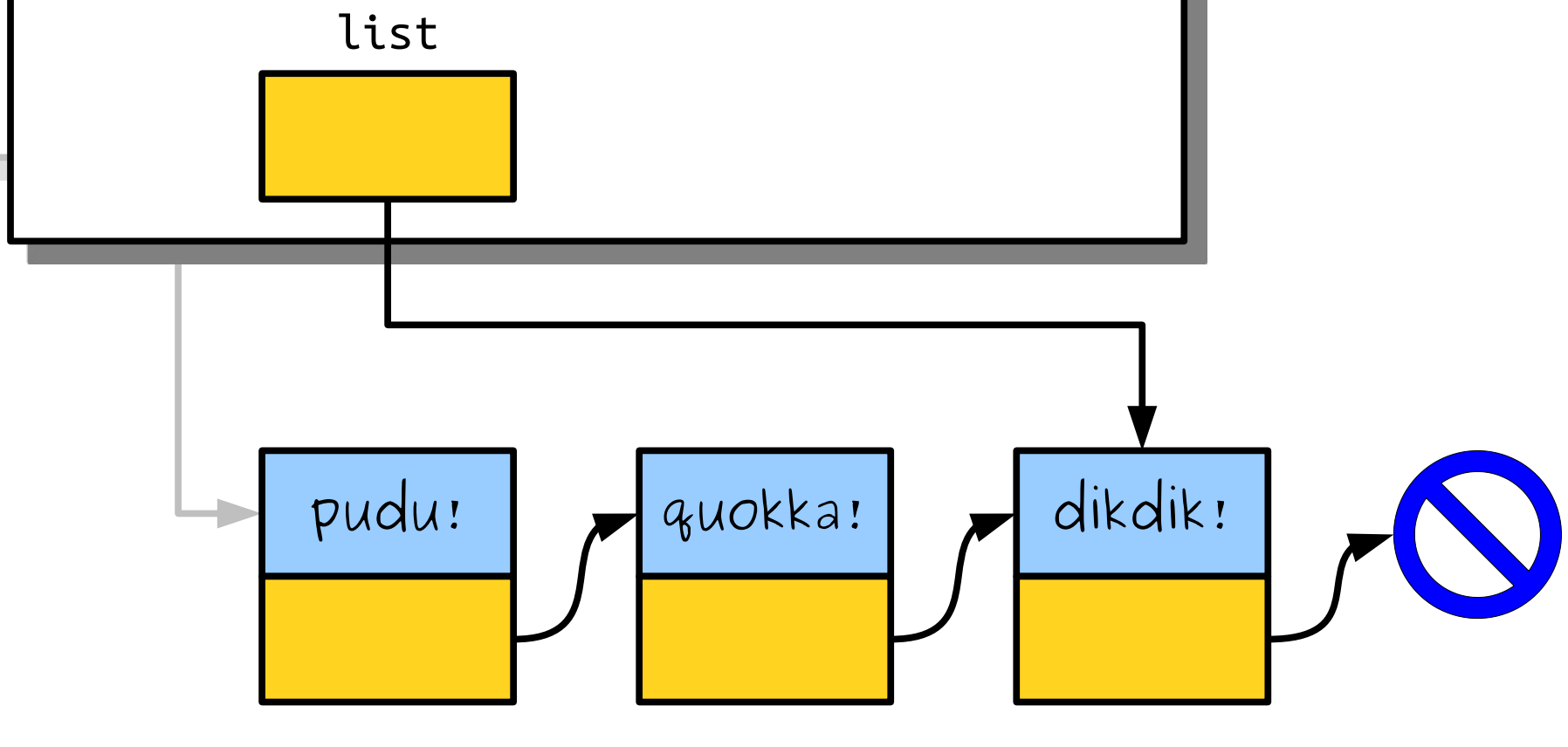

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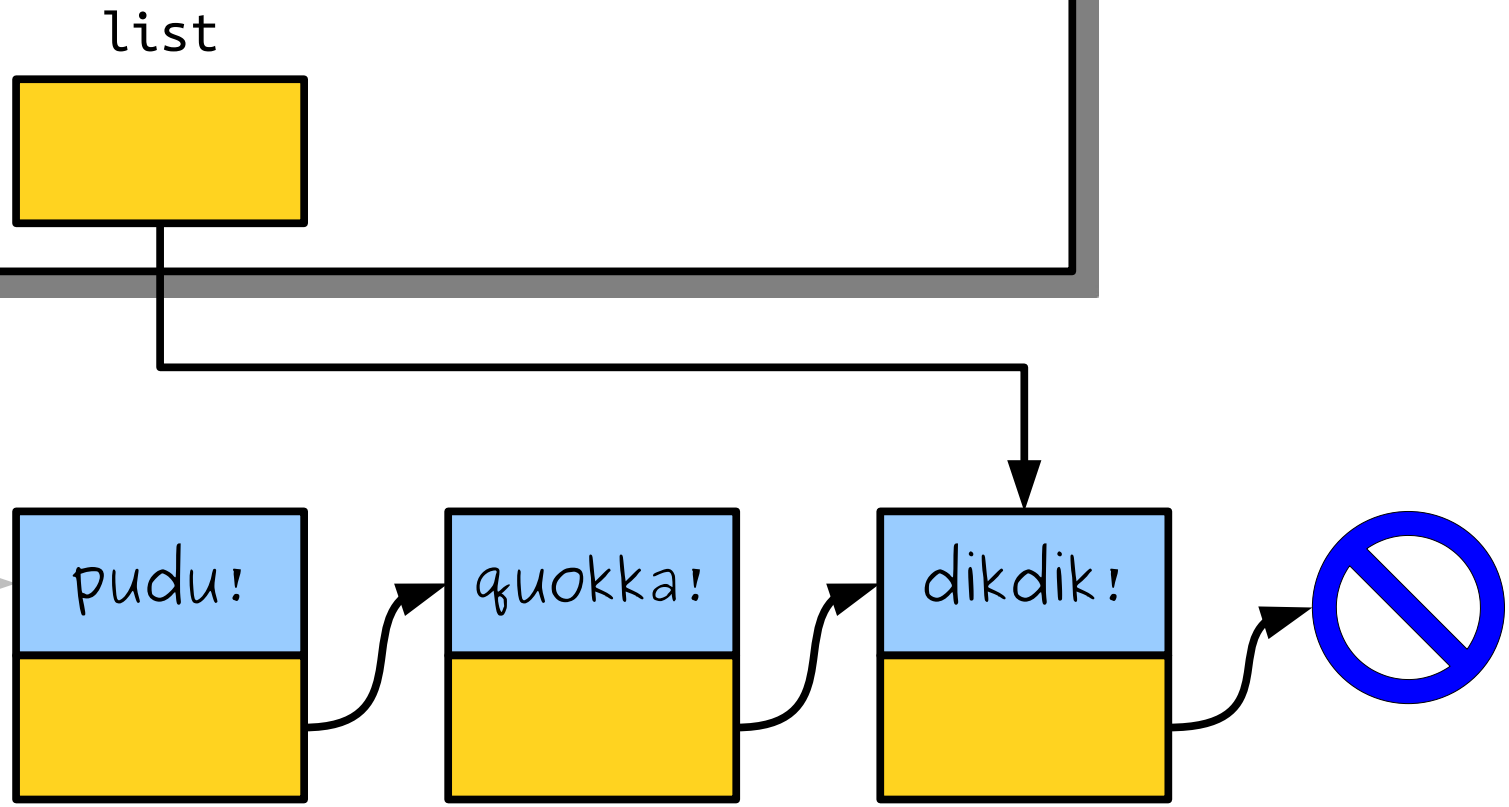

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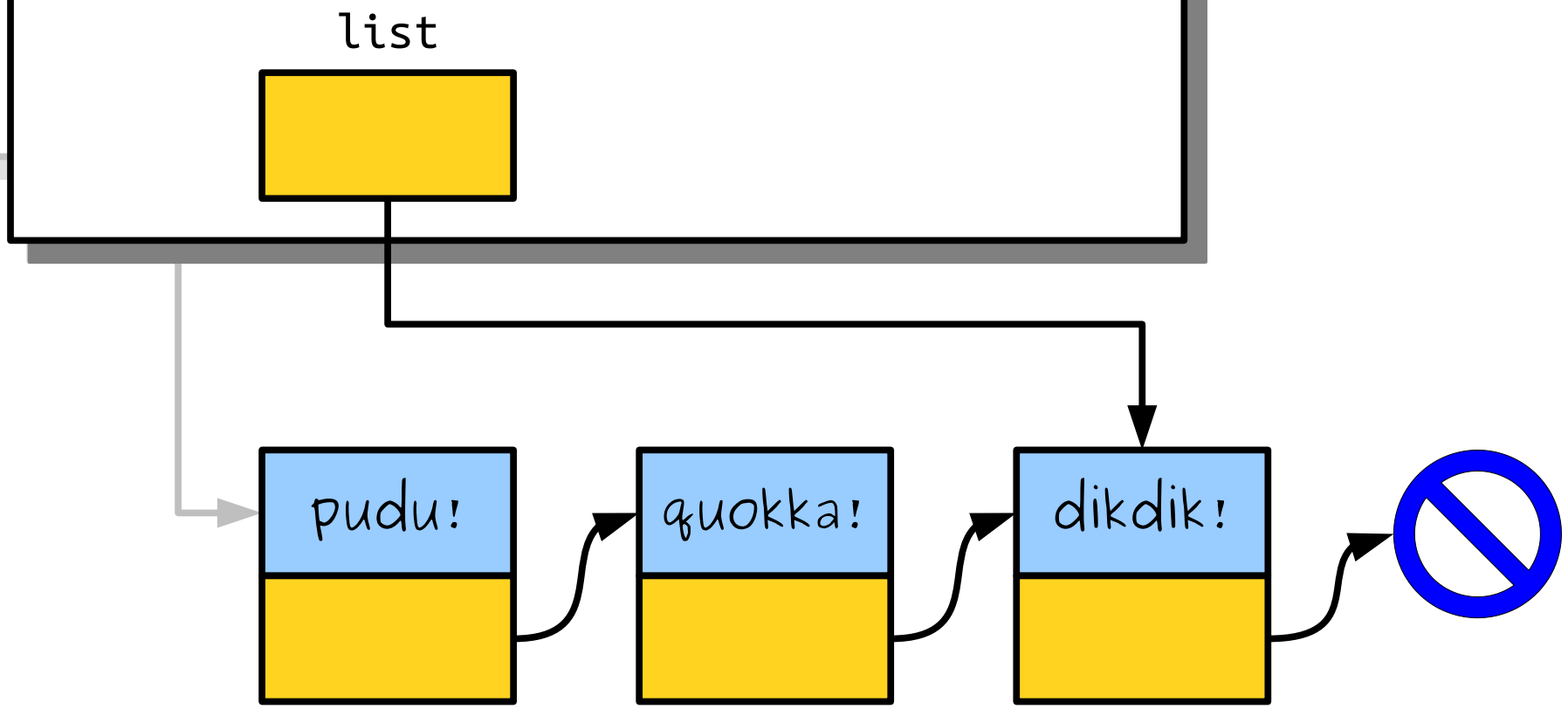
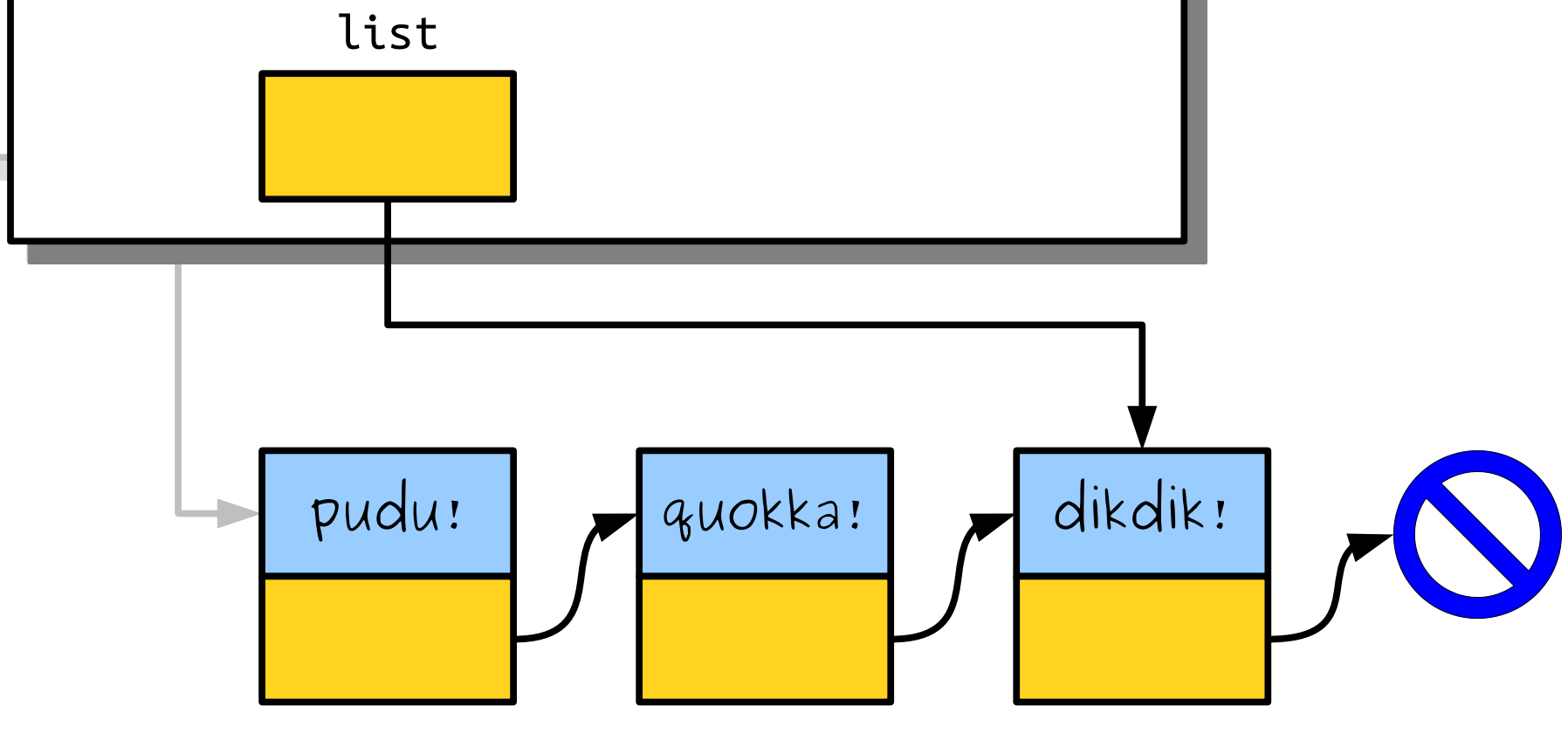


```
int main() {
```

```
void printList(Cell* list) {
    while (list != nullptr) {
        cout << list->value << endl;
        list = list->next;
    }
}
```



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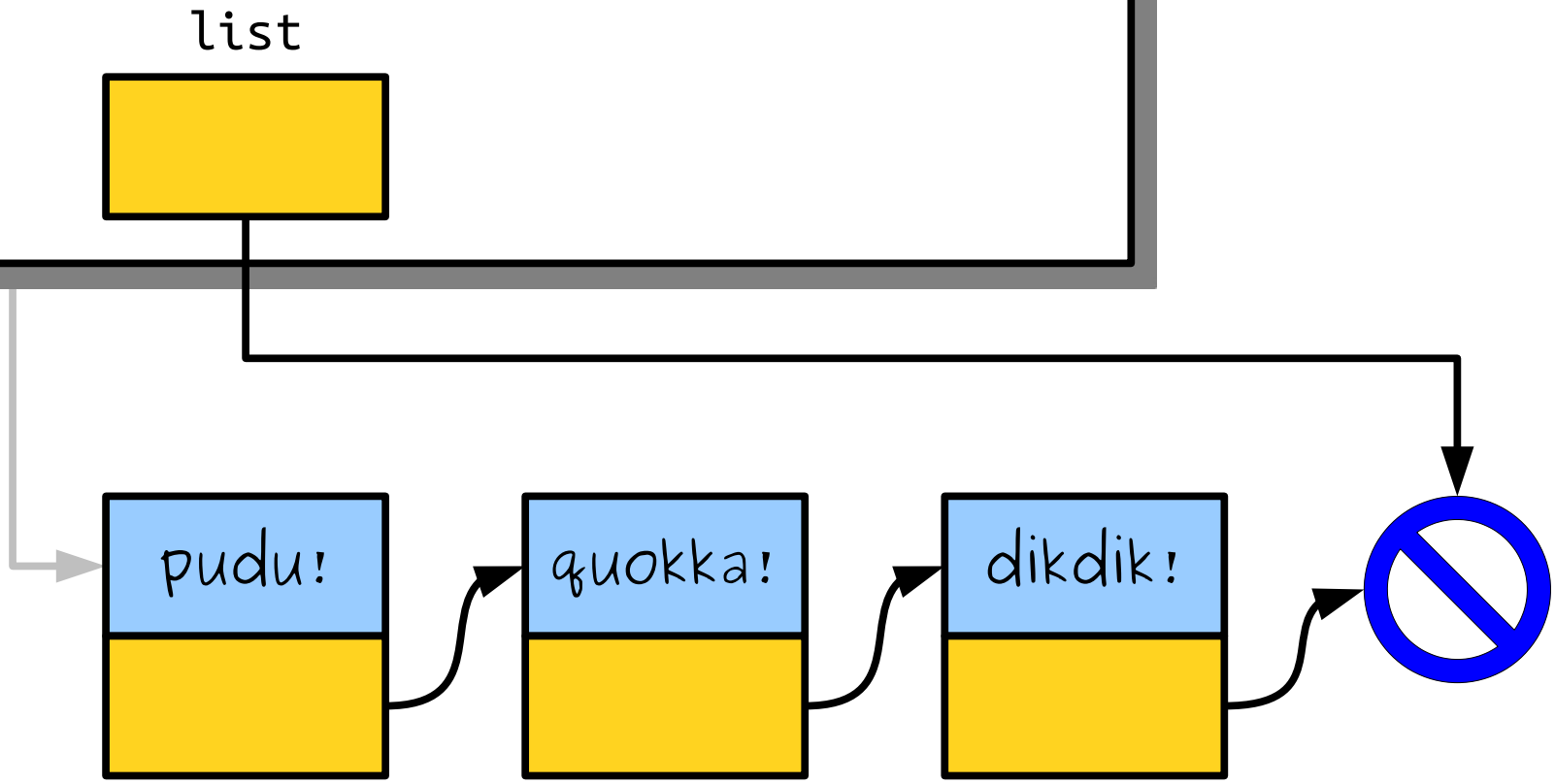

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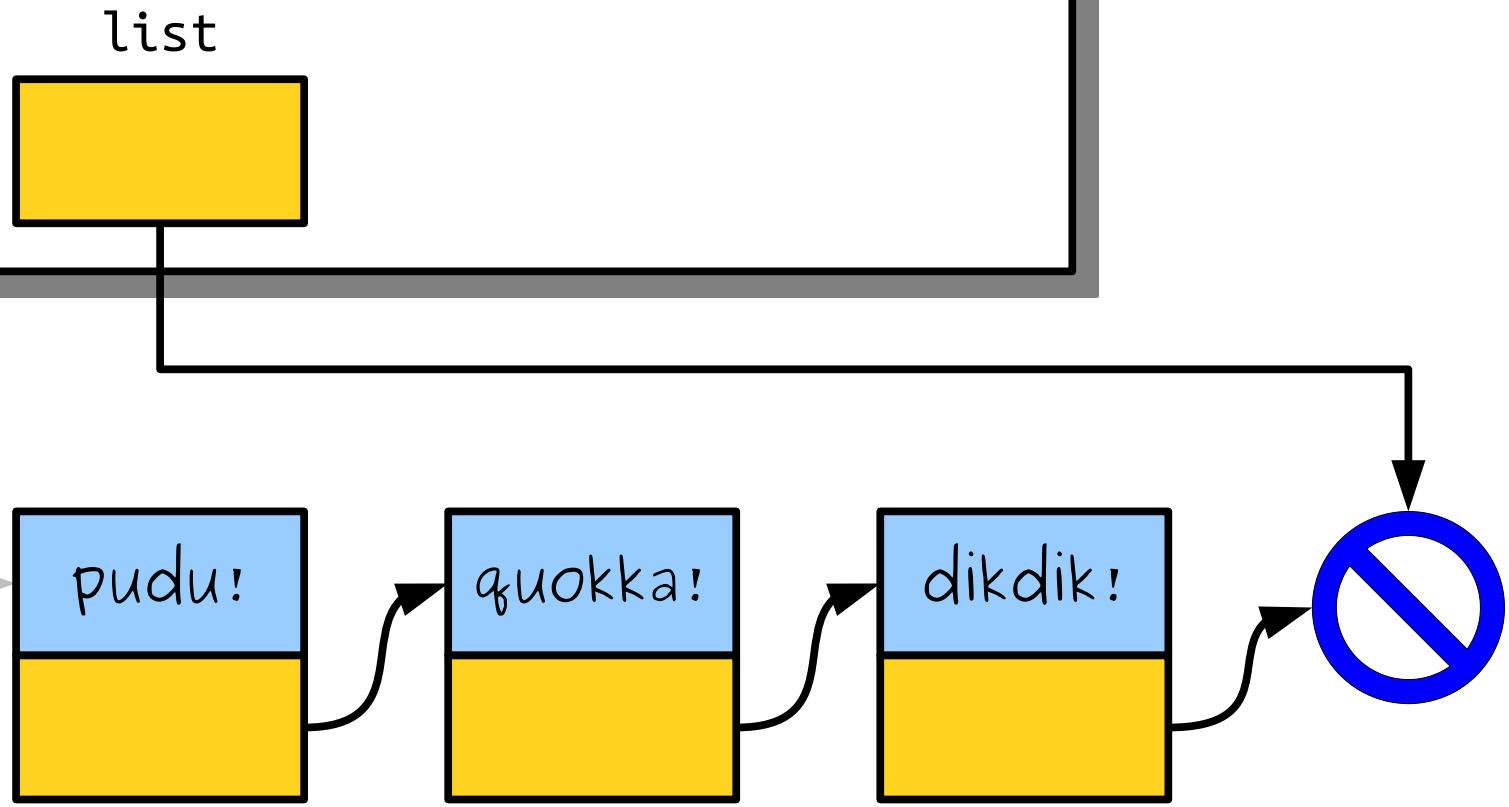
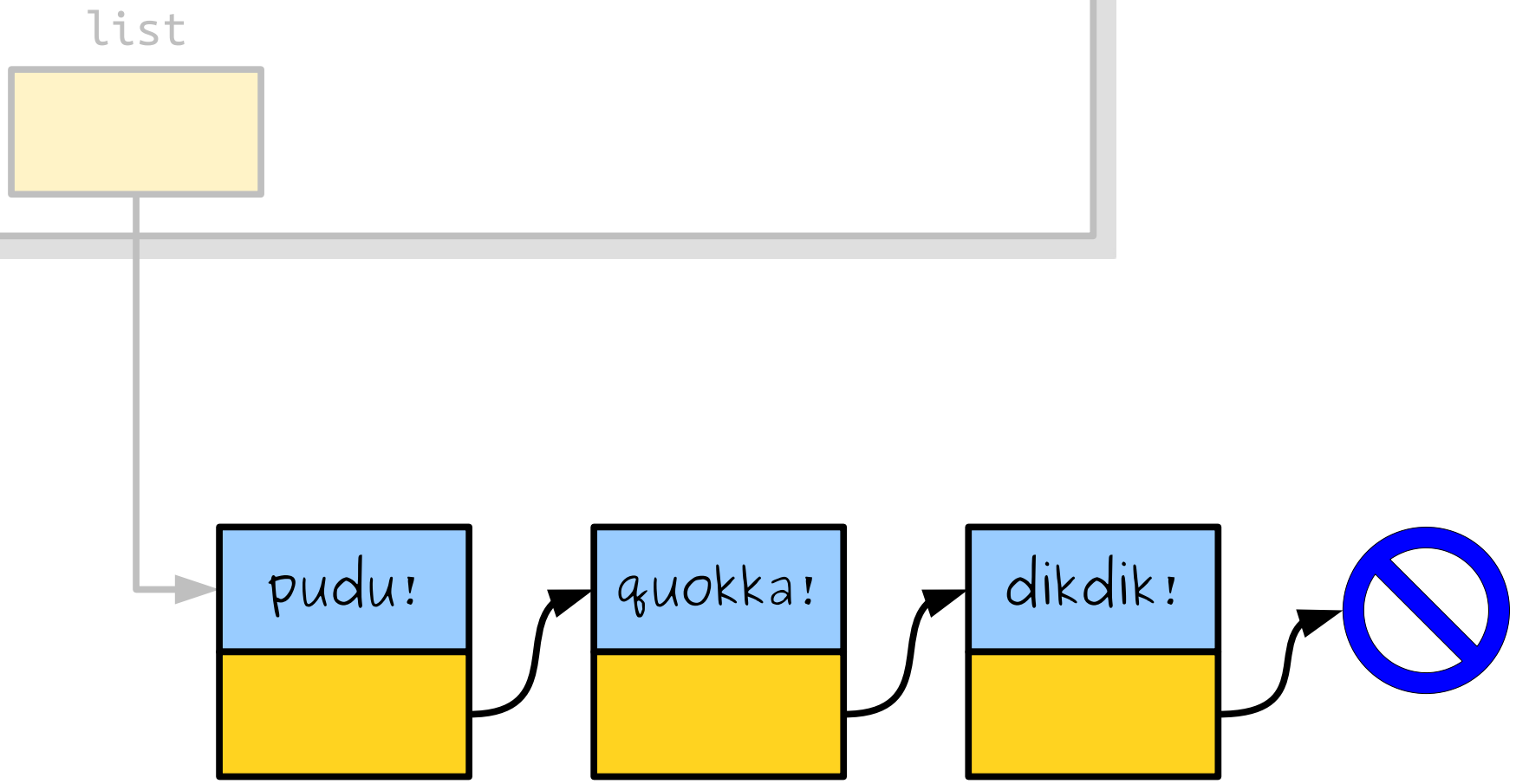


```
int main() {
   Cell* list = /* … a list … */;
   printList(list);

   /* … other listy things. … */
}
```



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int main() {
    Cell* list = /*  … a list … */;
    printList(list);

    /* … other listy things. … */
}
```

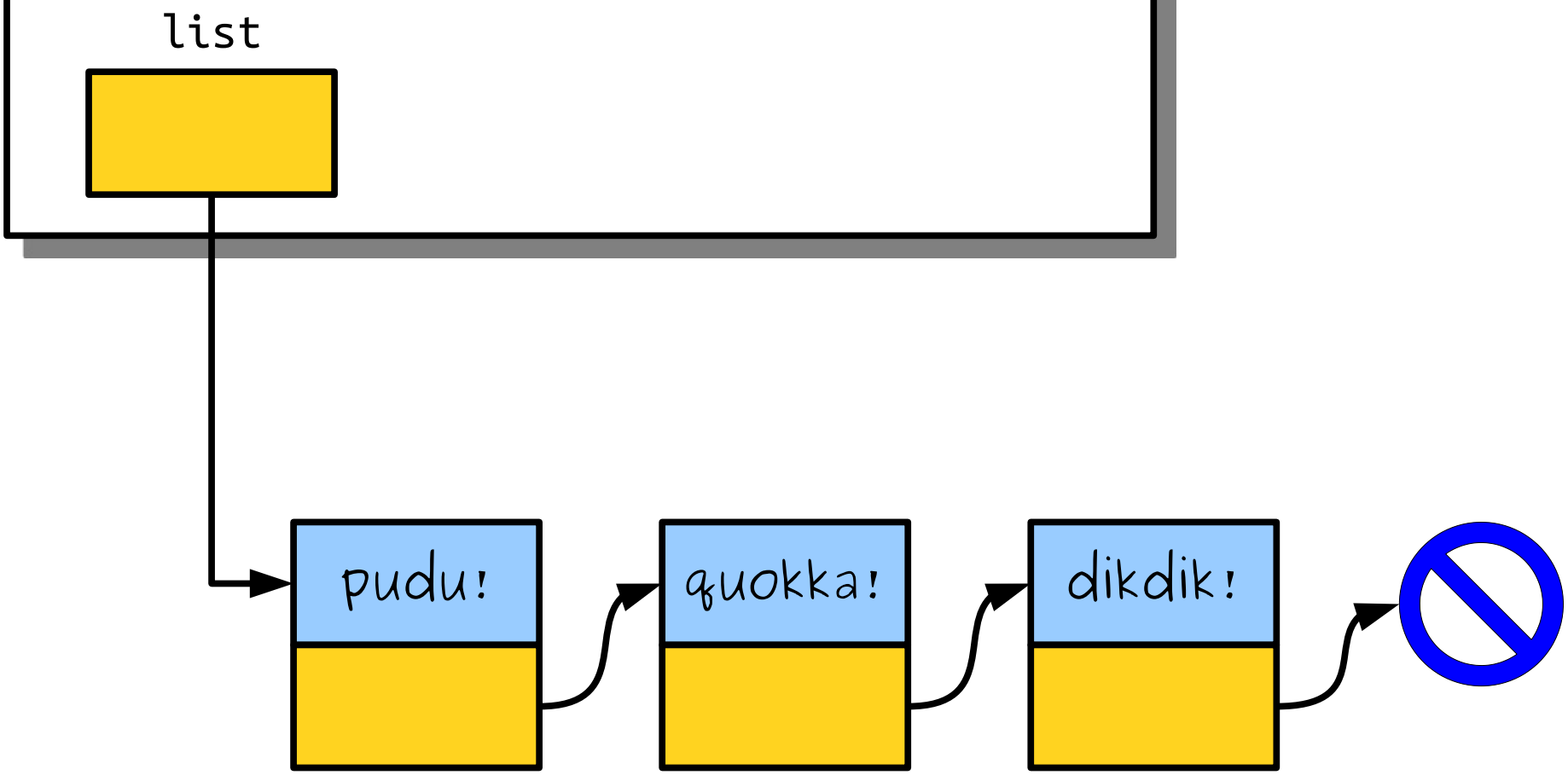

What will happen if we reverse these two lines?

Formulate a hypothesis!

What will happen if we reverse these two lines?

Discuss with your neighbors!

```
int main() {
    Cell* list = /* … a list … */;
    printList(list);

    /* … other listy things. … */
}
```

```
int main() {
    Cell* list = /* … a list … */;
    printList(list);

    /* … other listy things. … */
}
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```
int main() {
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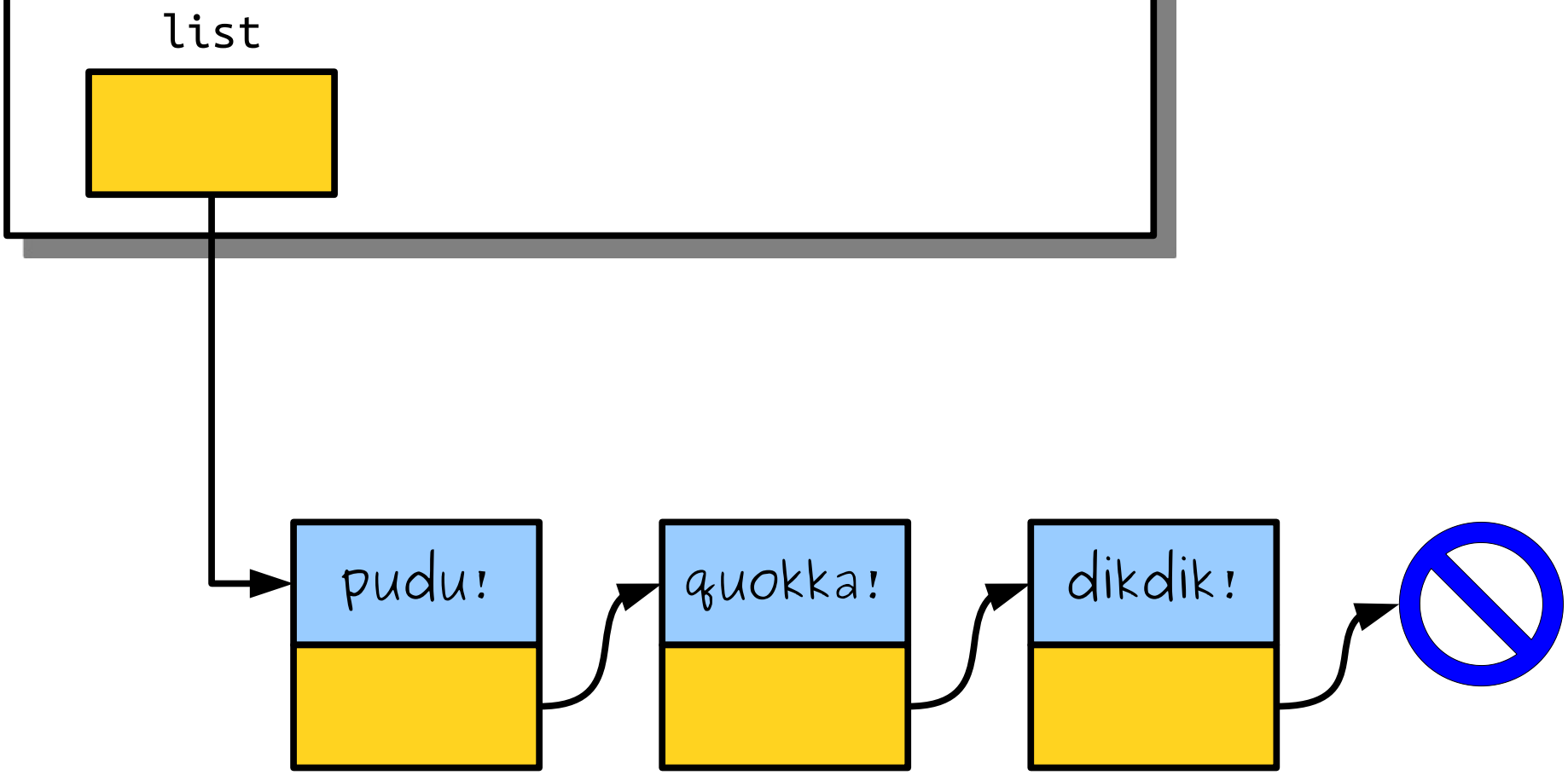

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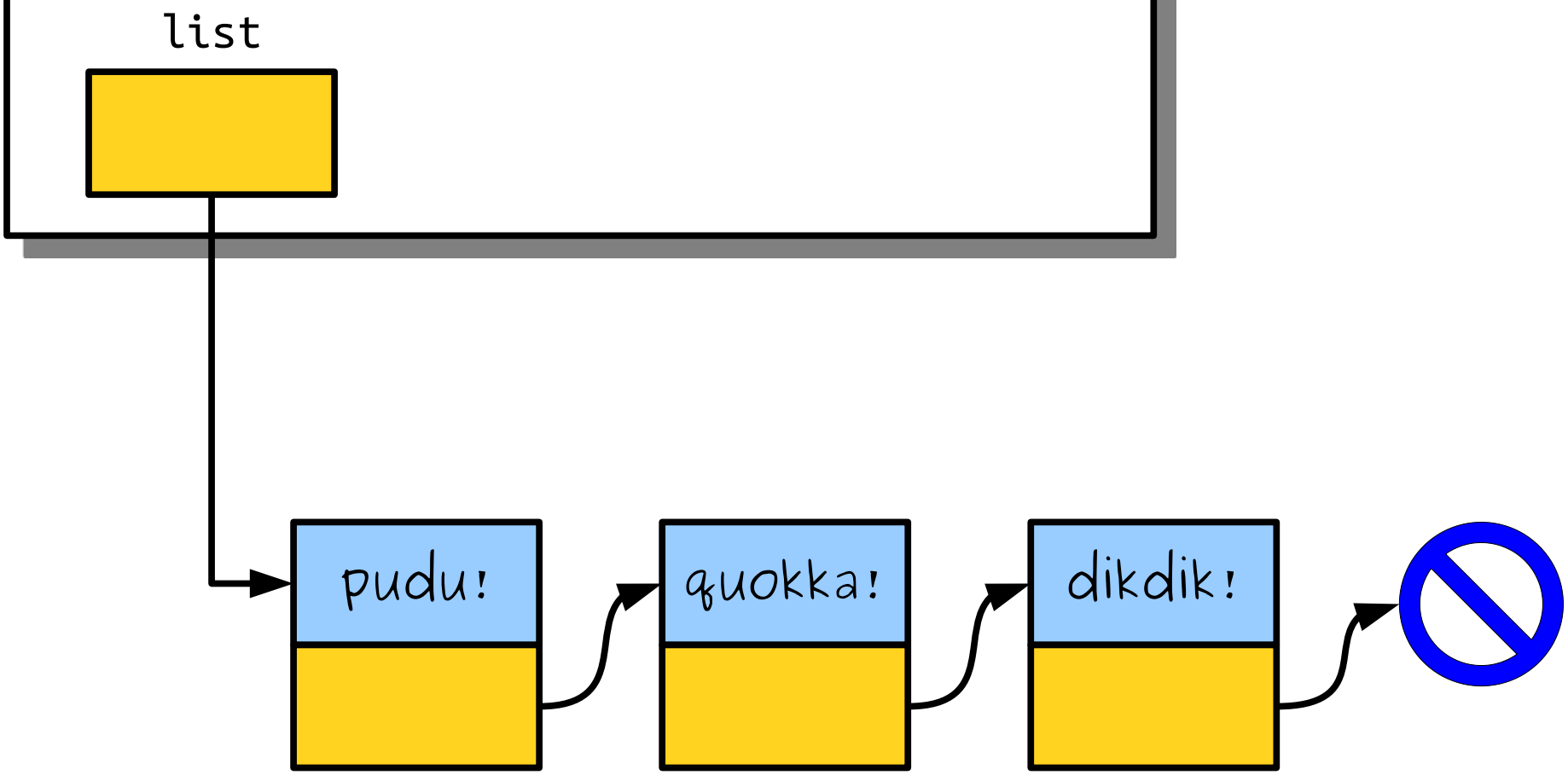

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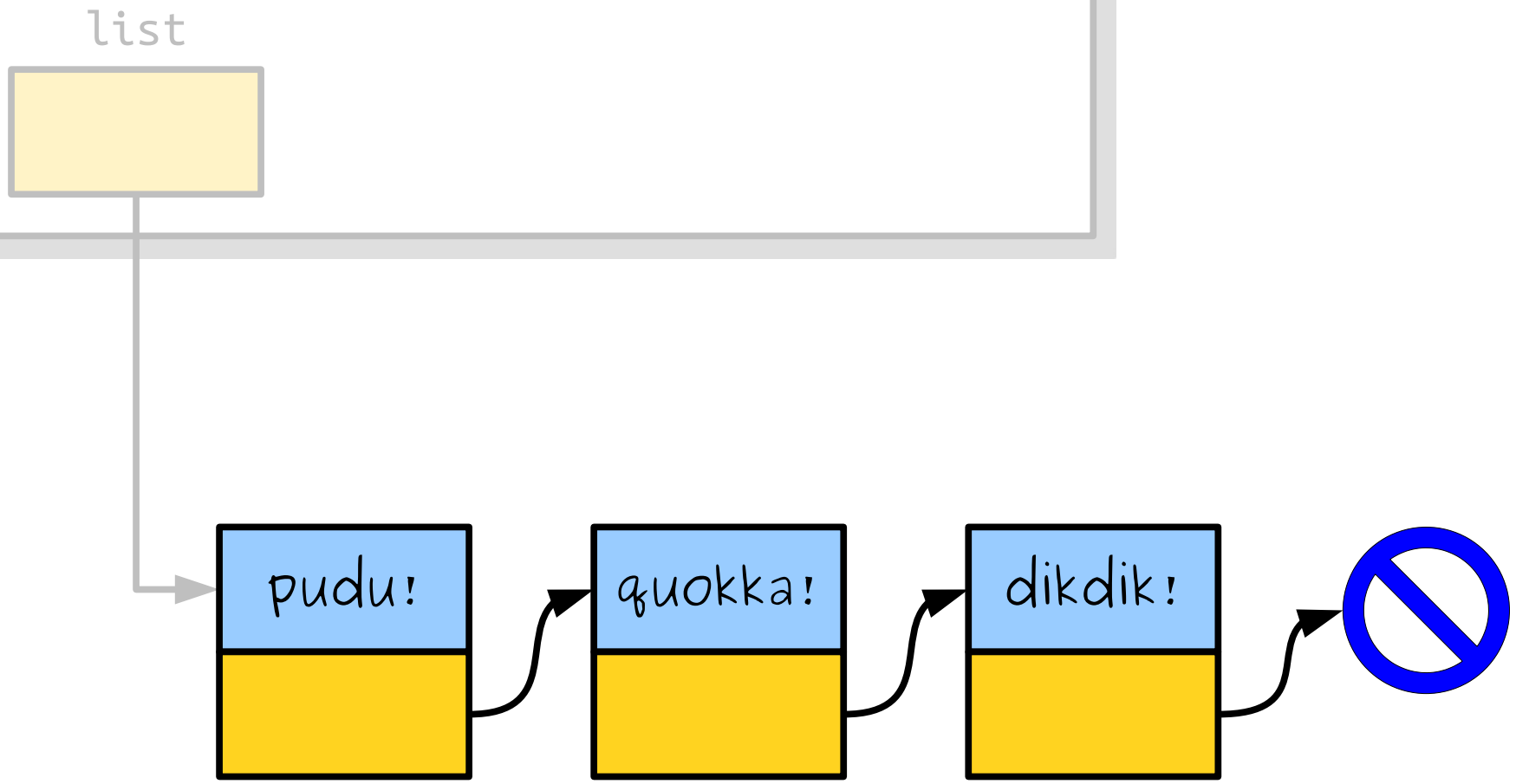

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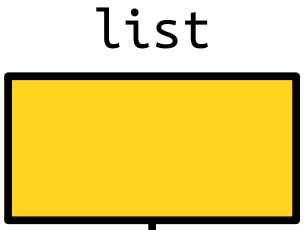

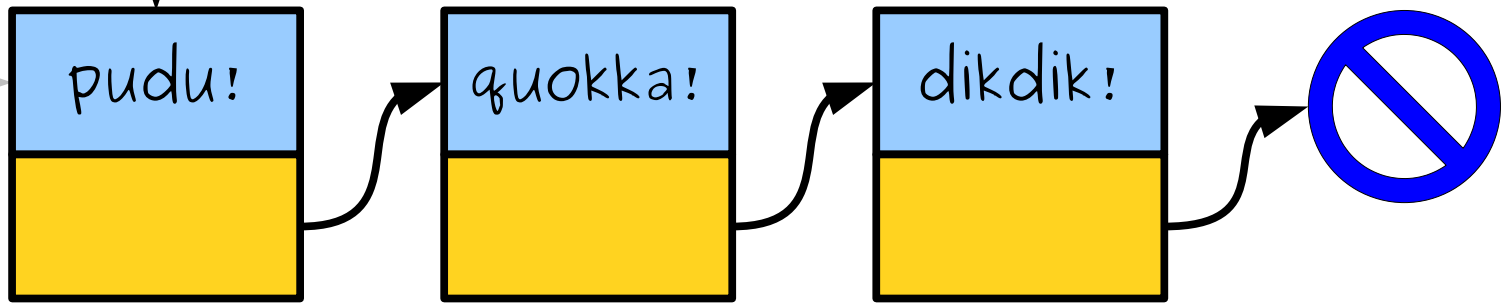

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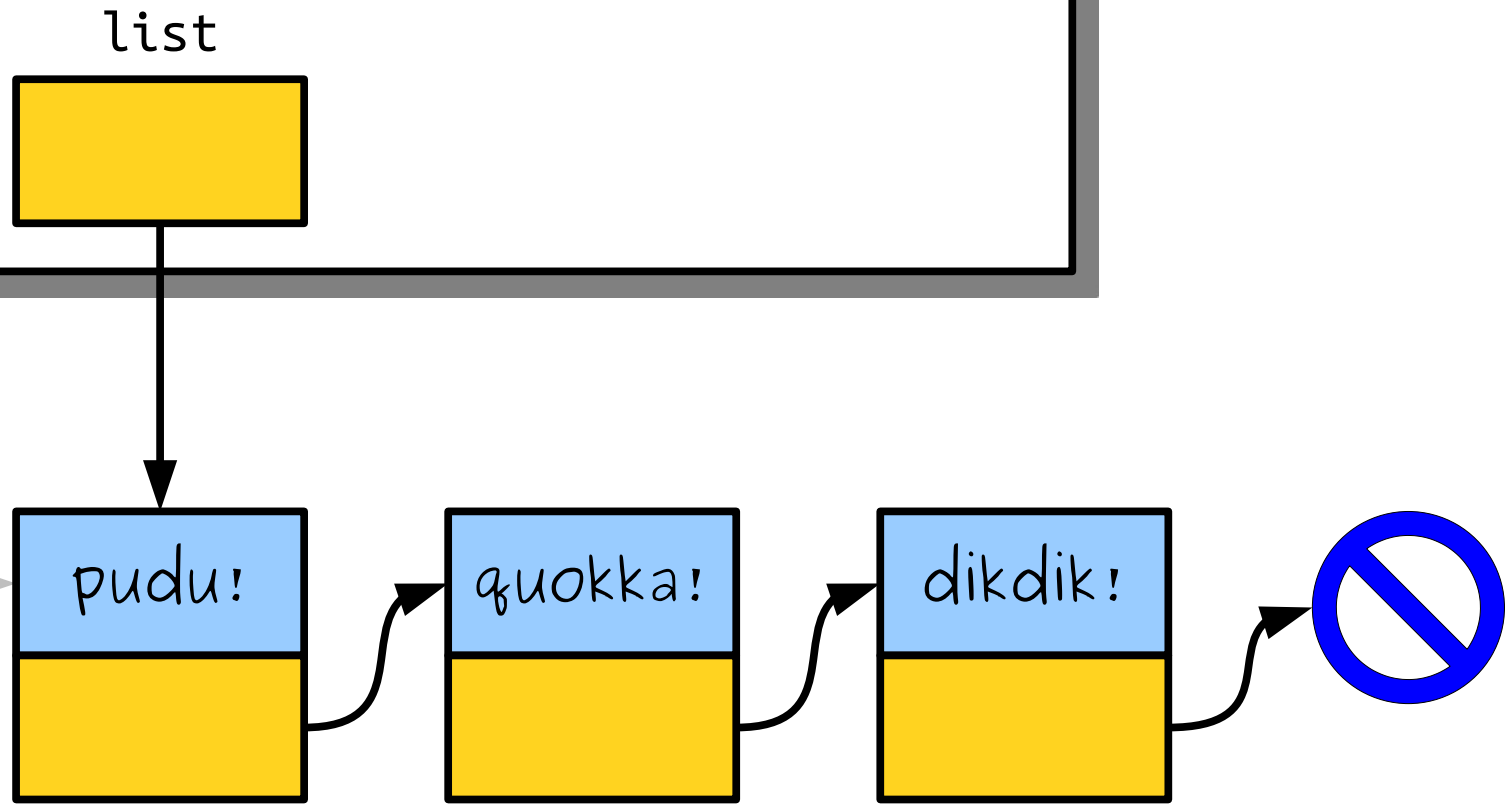

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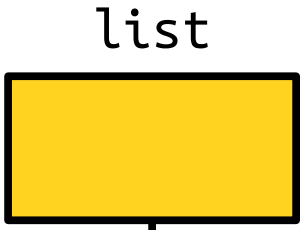

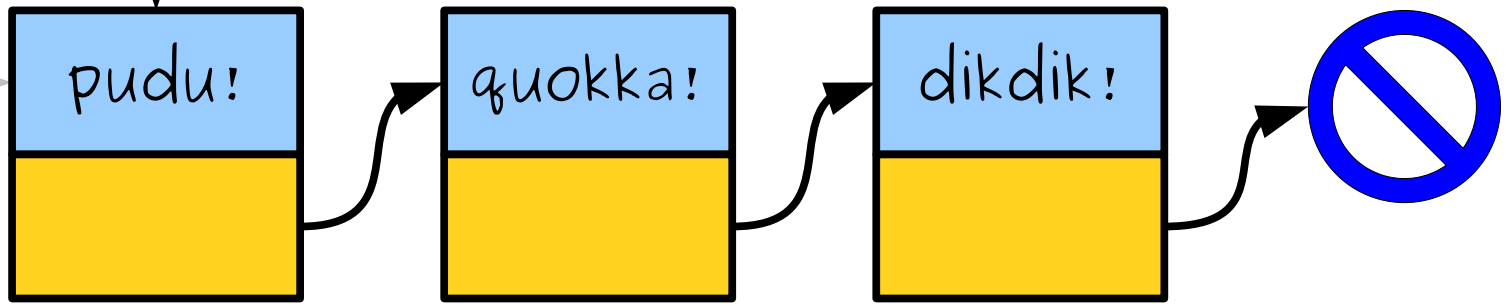

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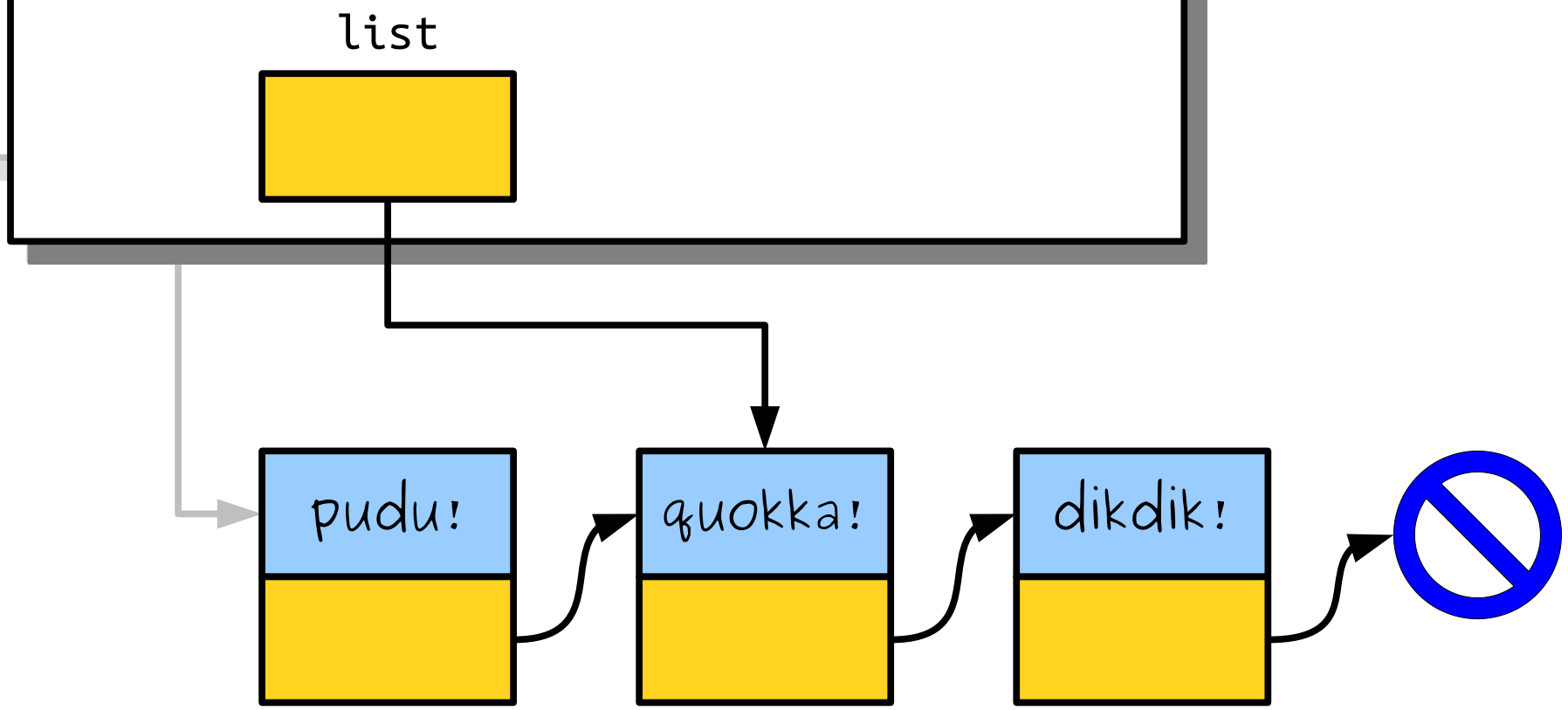

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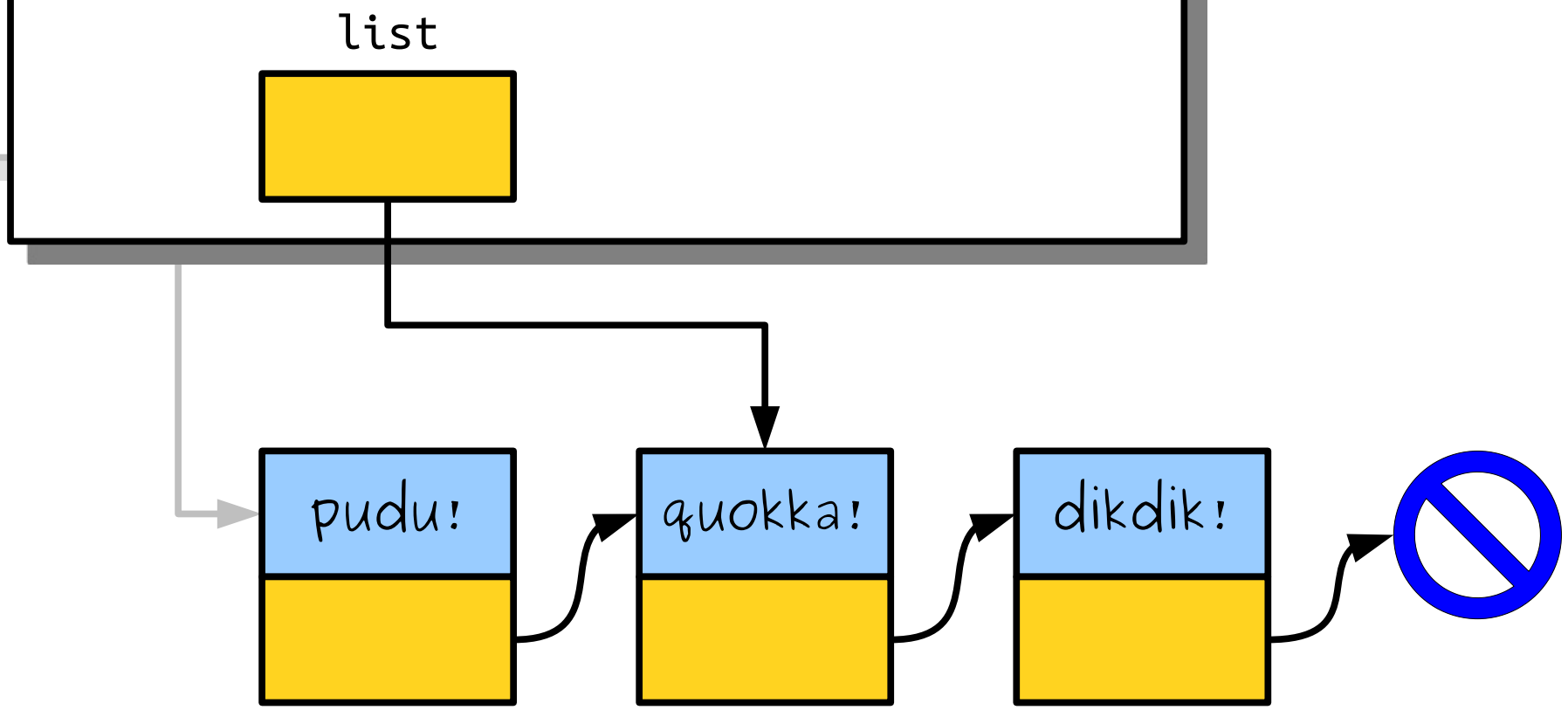

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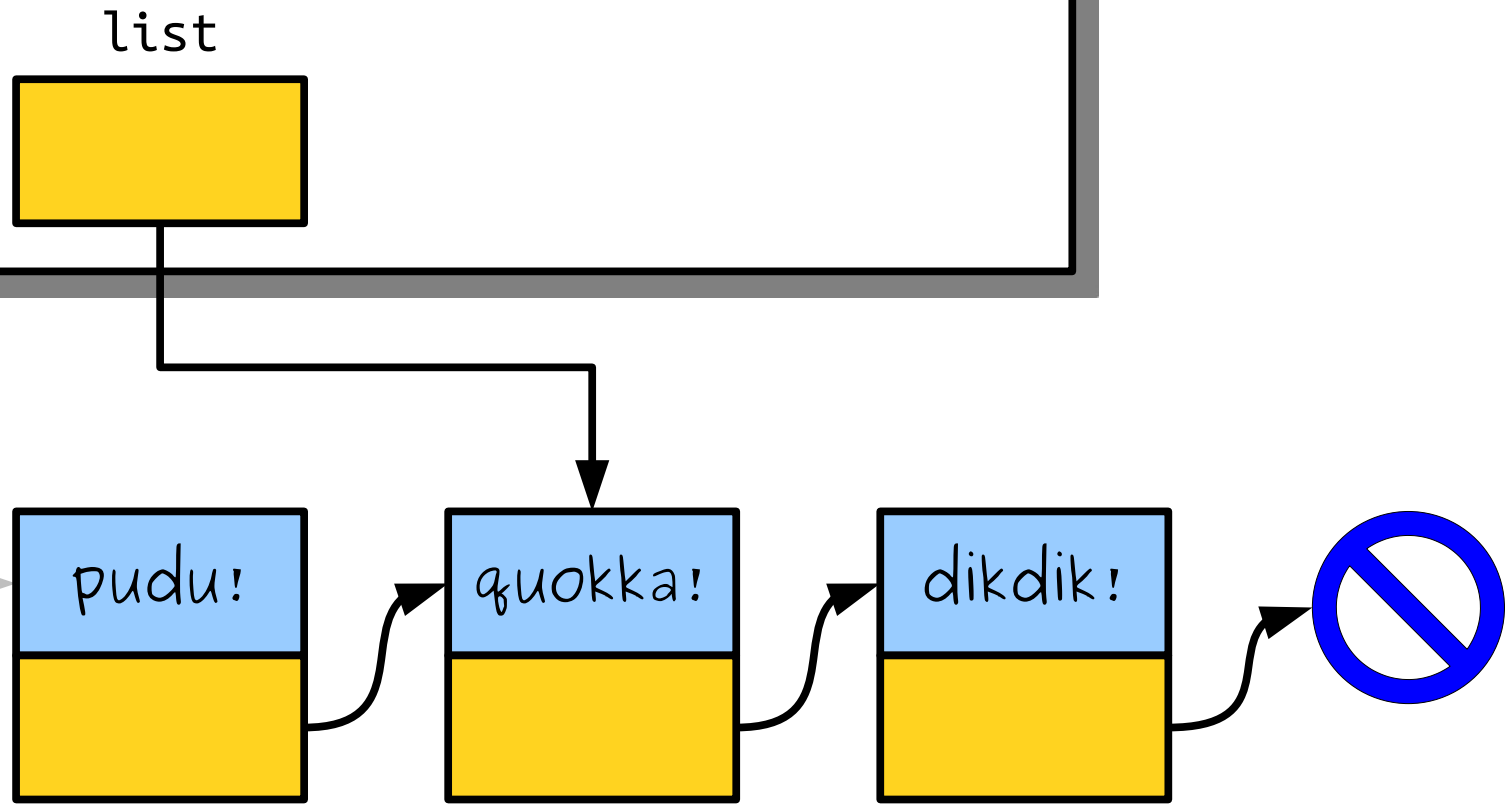

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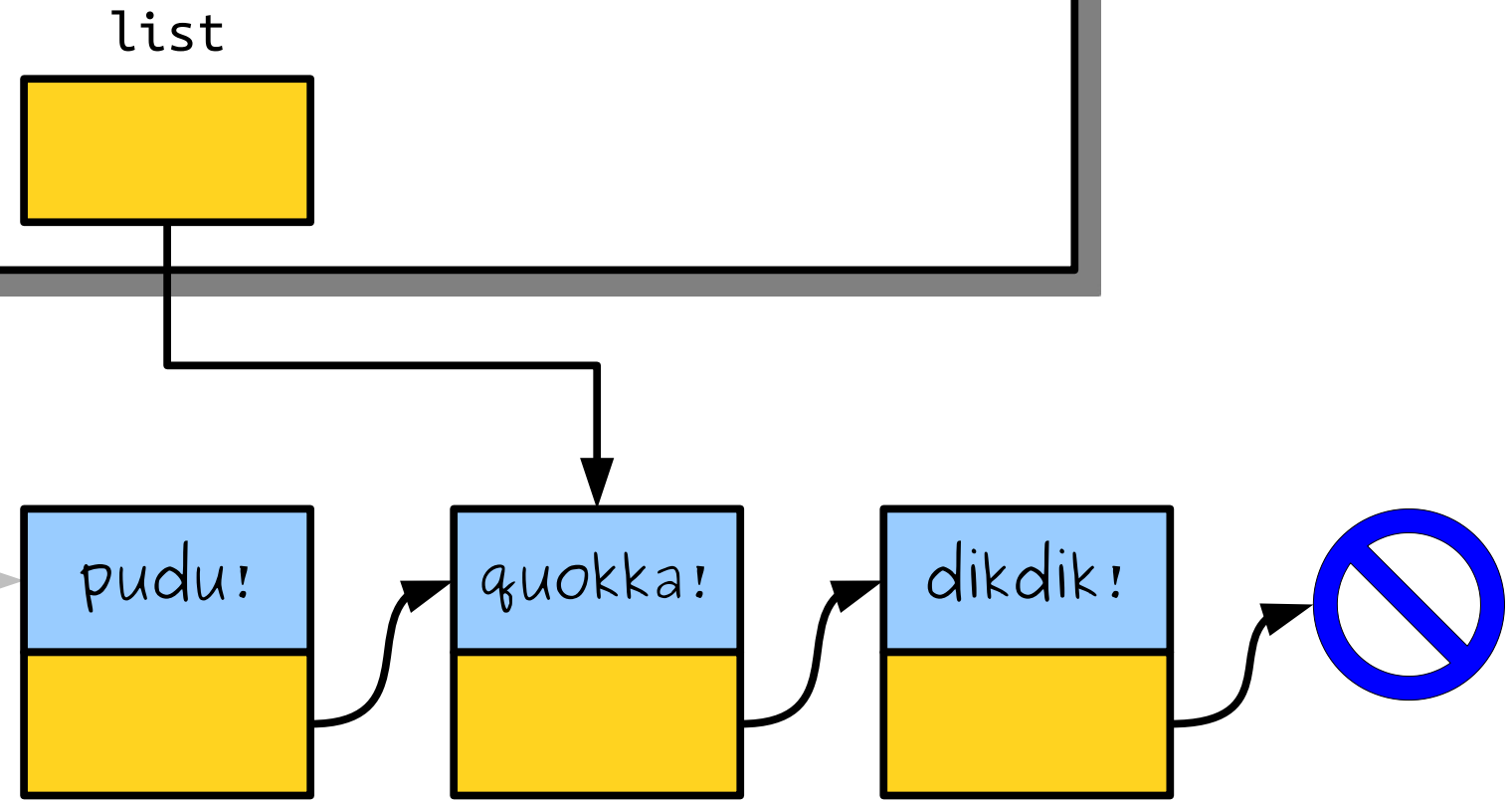

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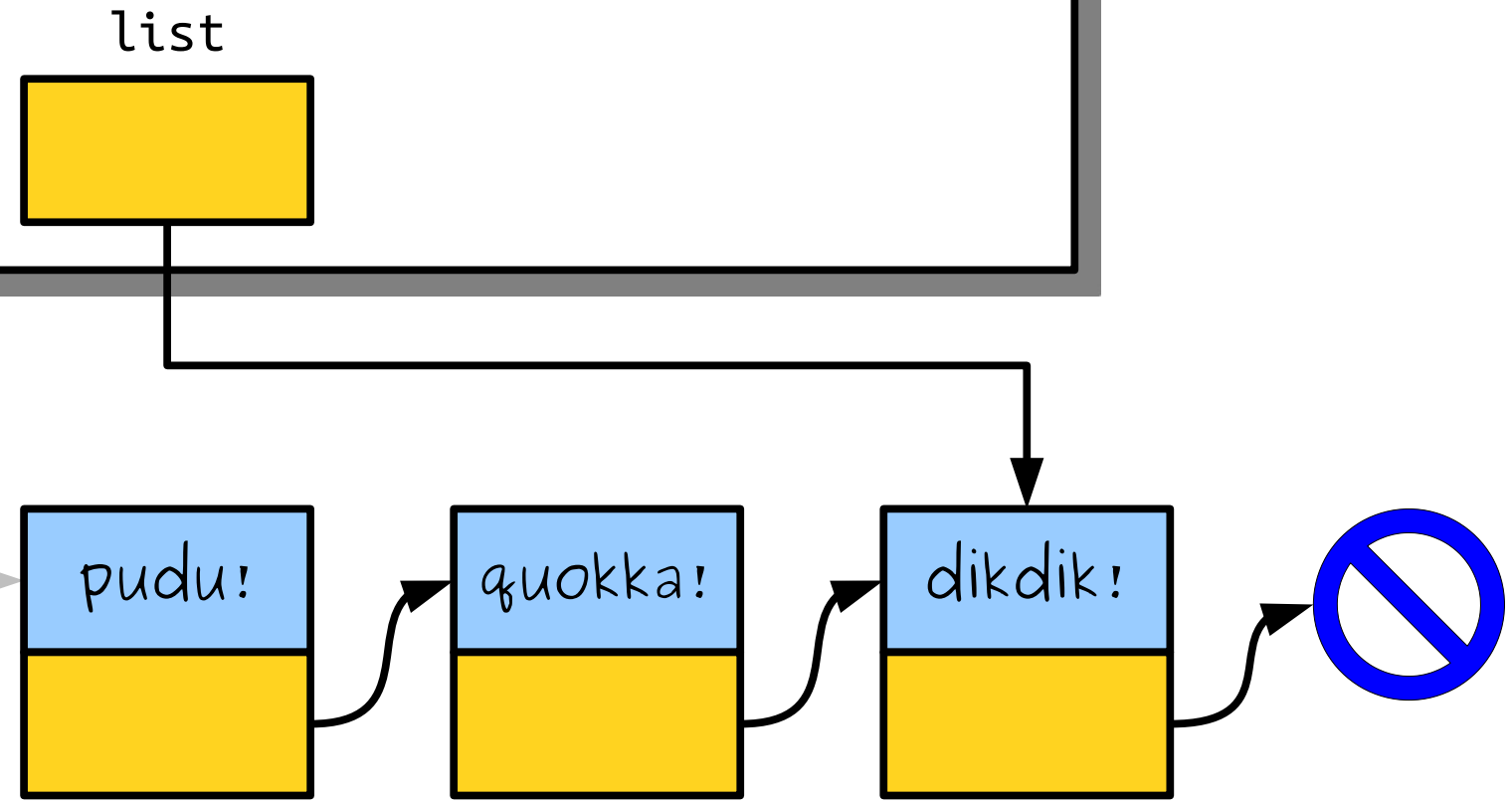

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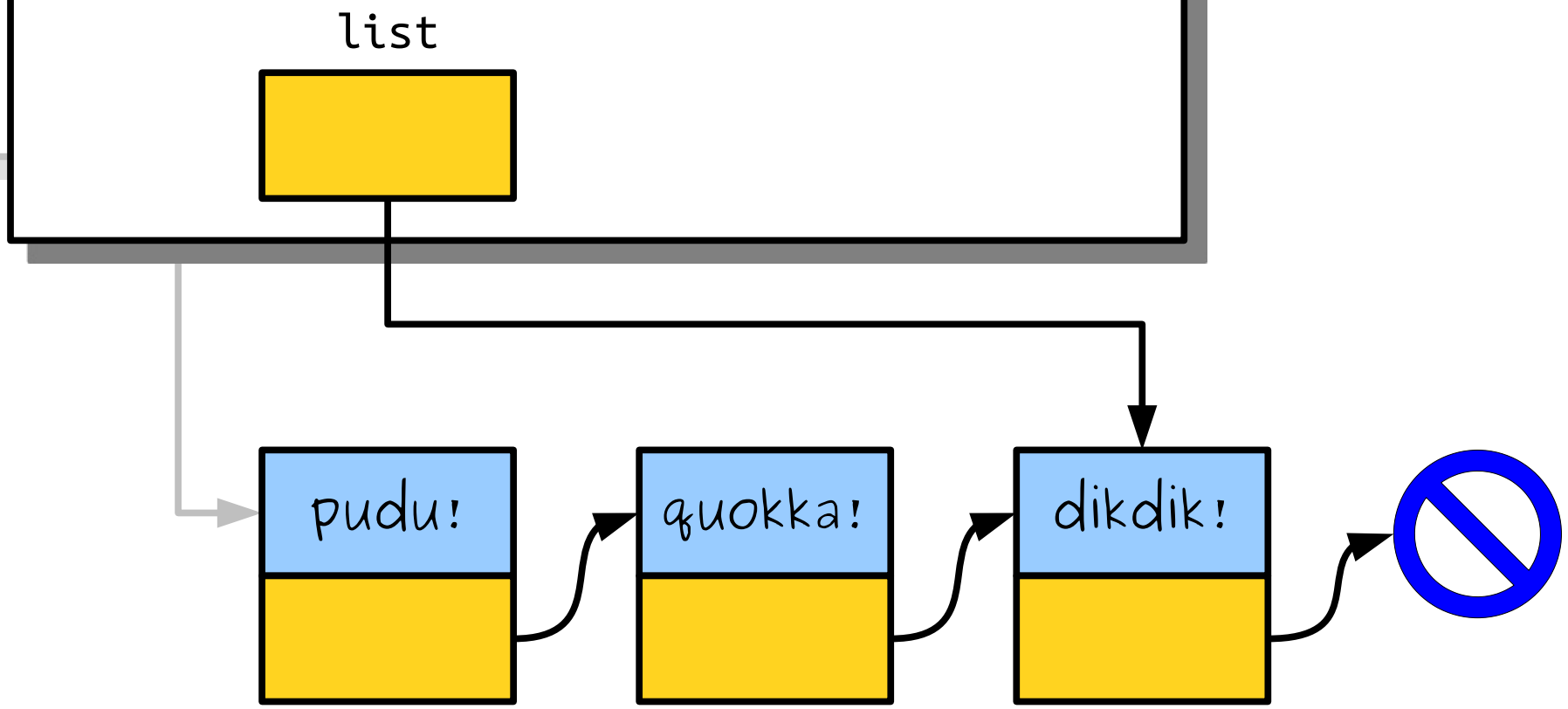

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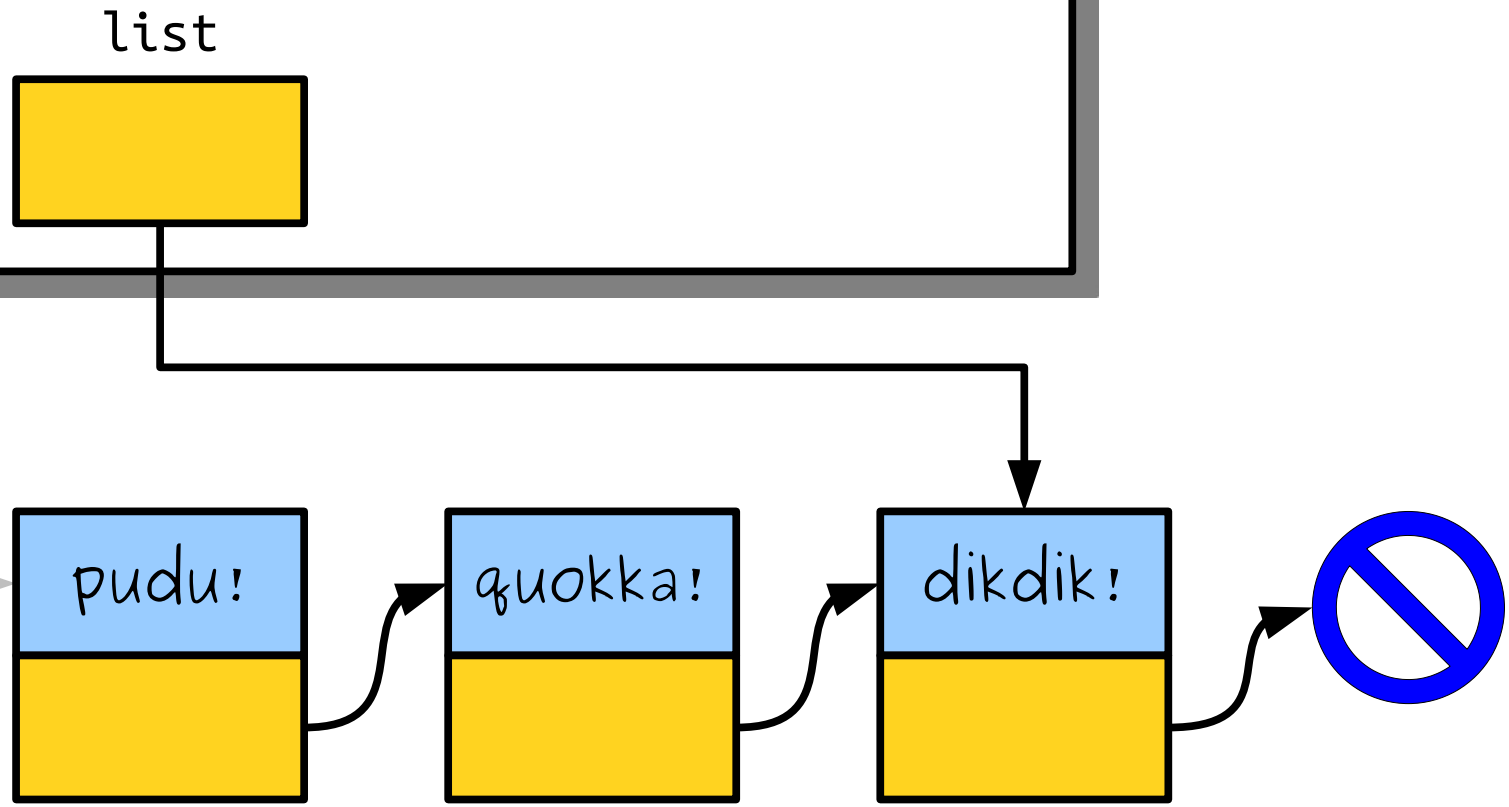

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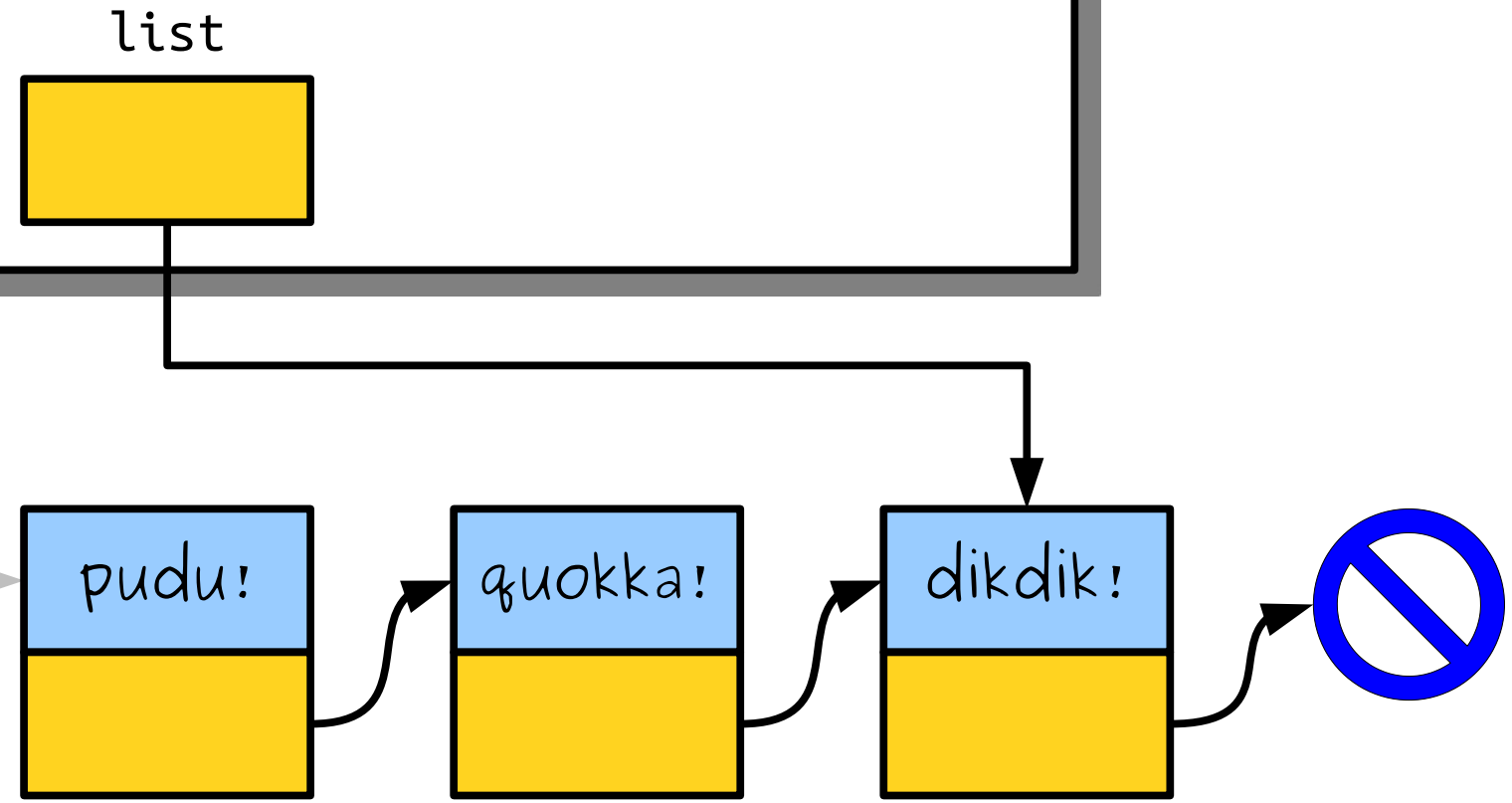

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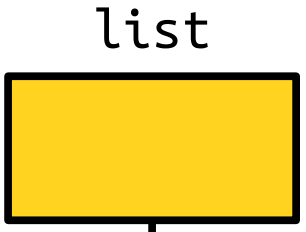

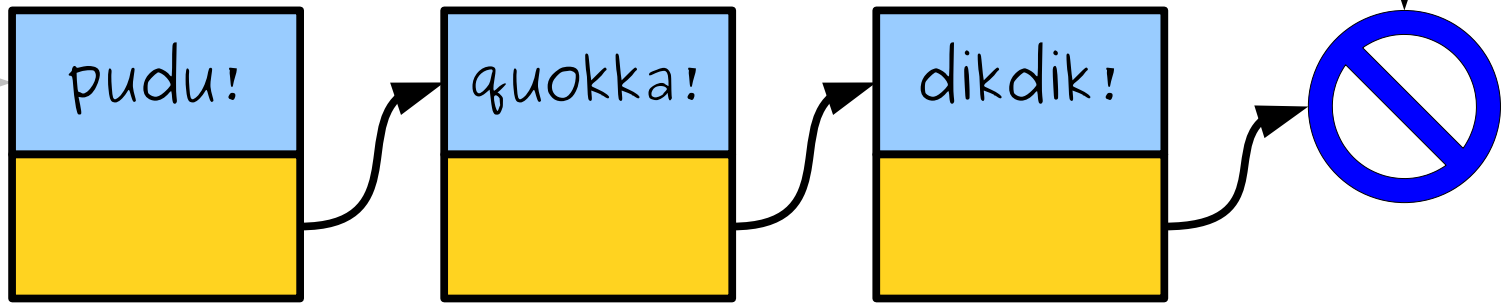

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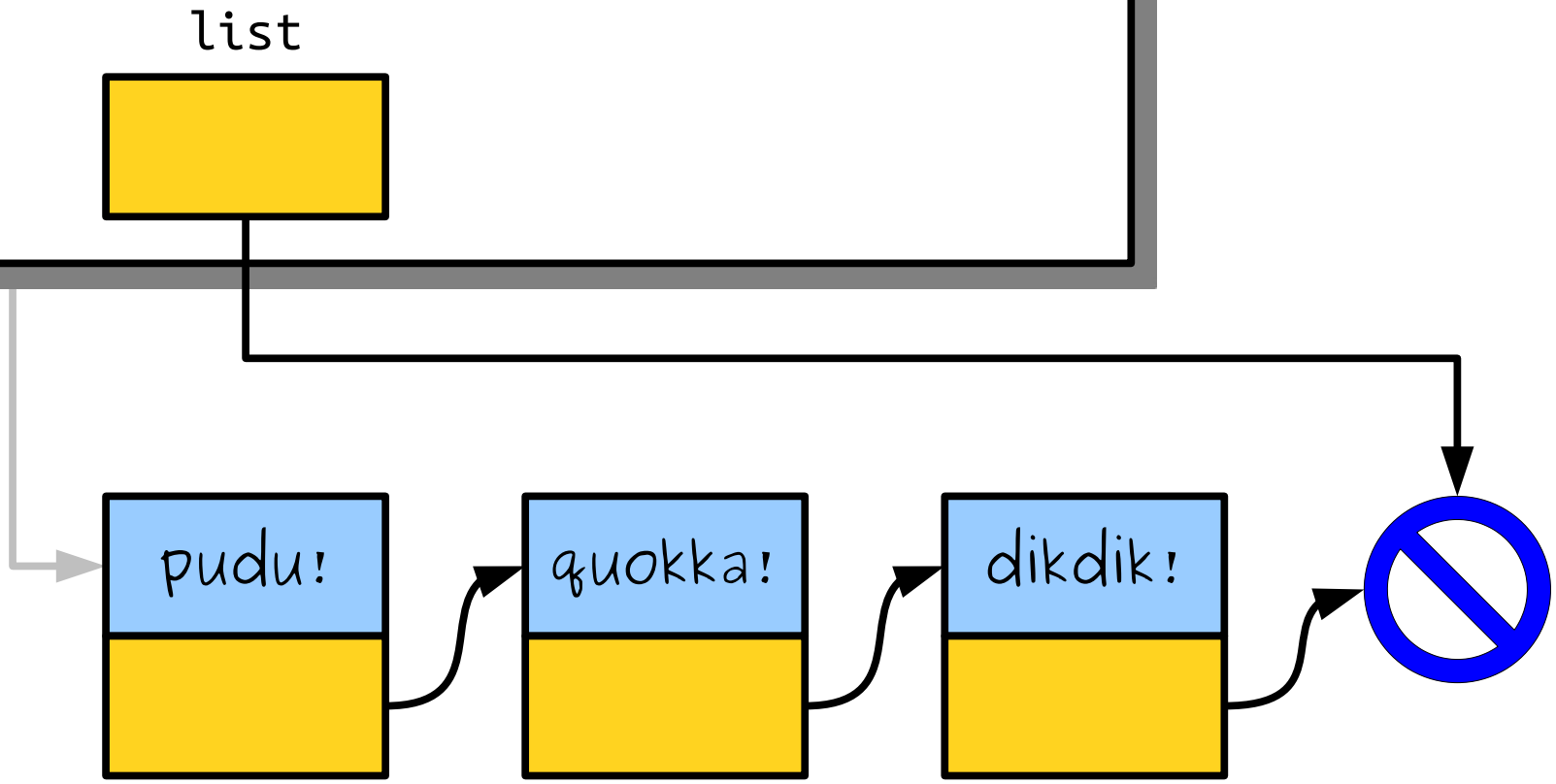

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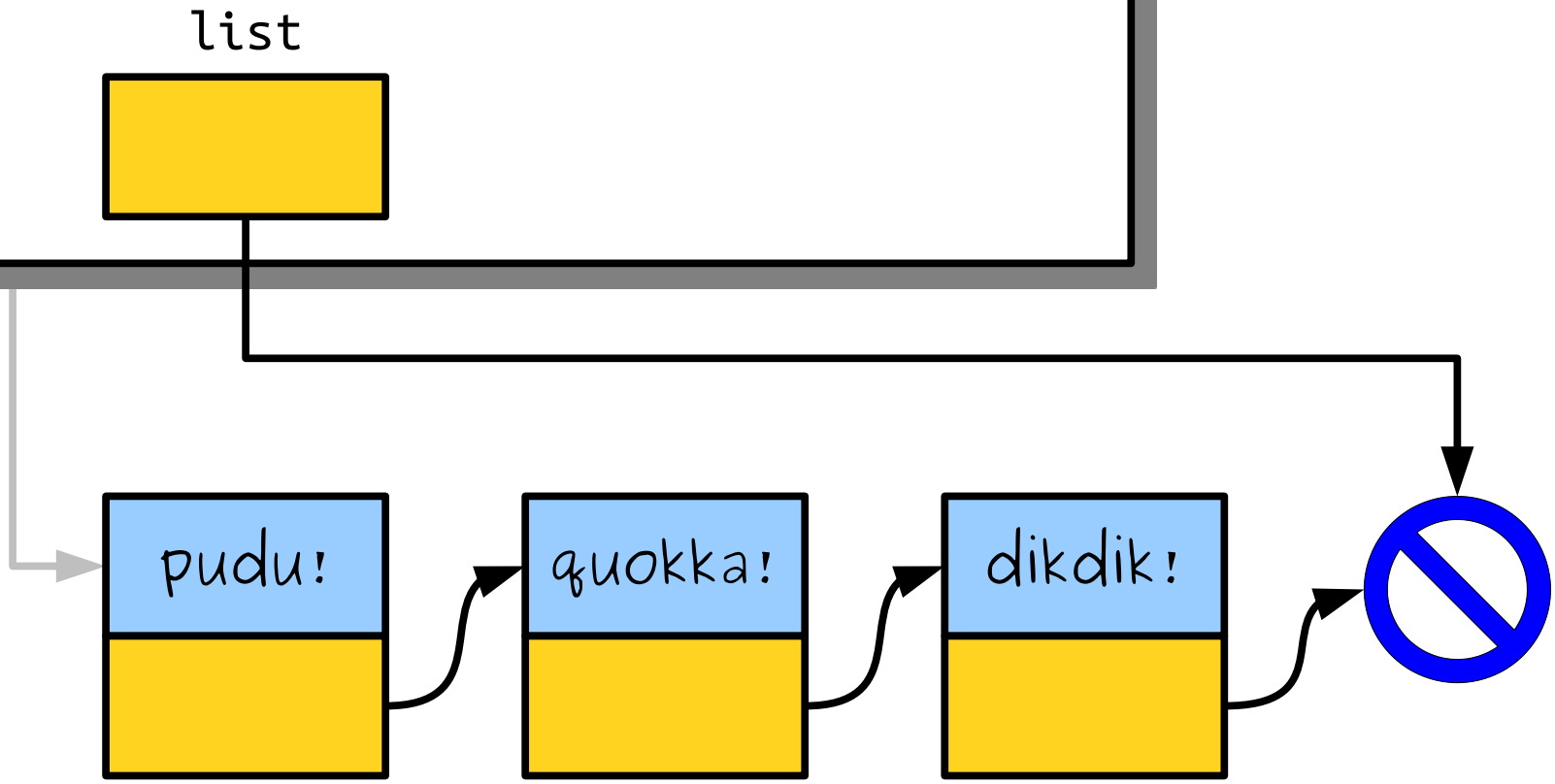

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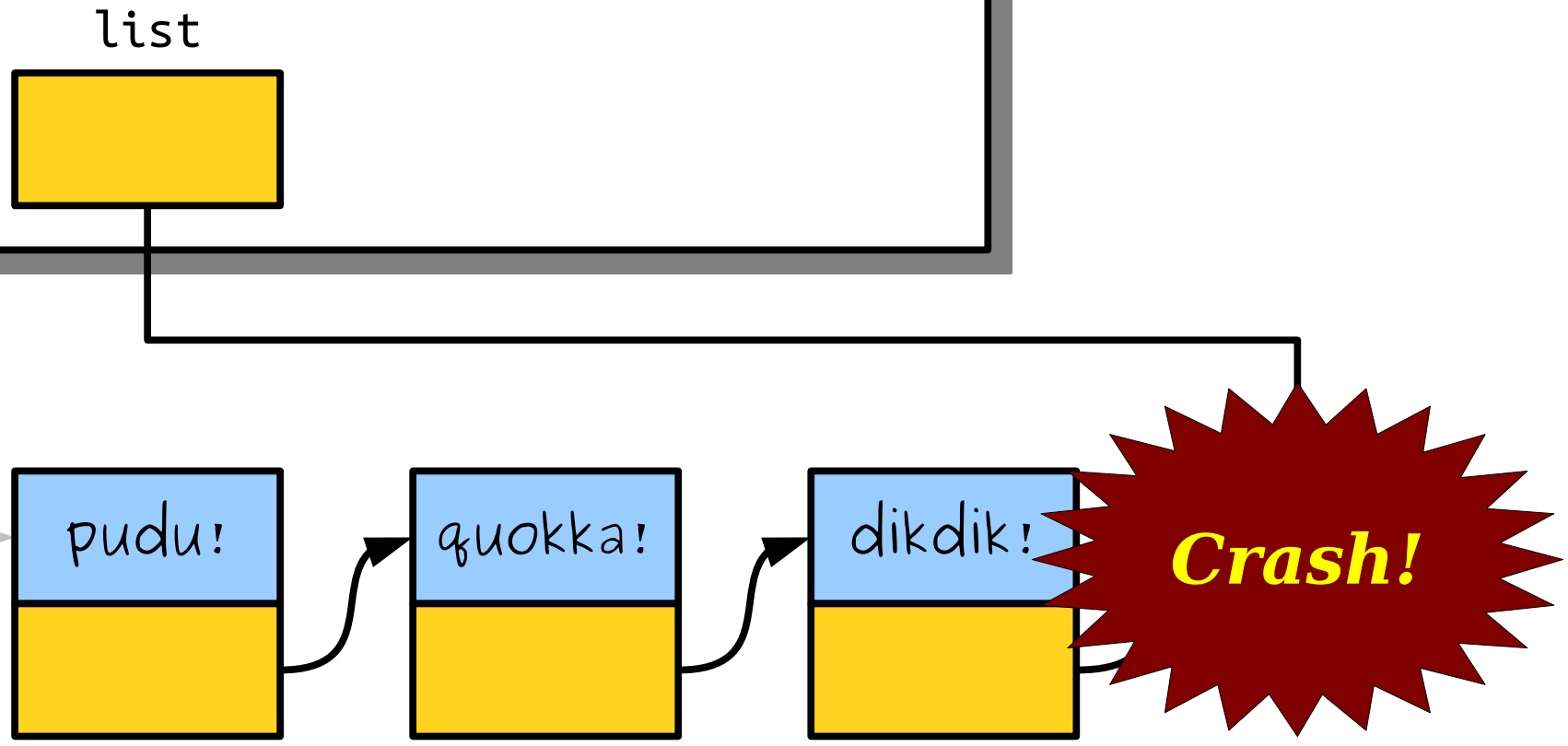
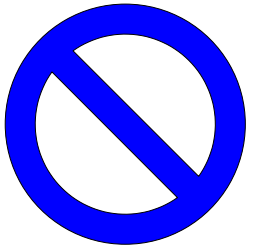


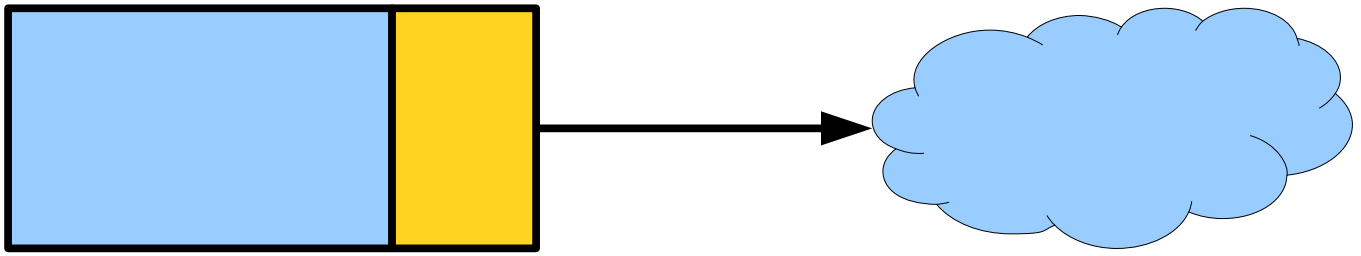
Building a Linked List

(without hardcoding it)

A Linked List is Either…

…an empty list, represented by `nullptr`, or…





a single linked list cell that points…

… at another linked list.

Cleaning Up a Linked List

Endearing C++ Quirks

- If you allocate memory using the `new[]` operator (e.g. `new int[137]`), you have to free it using the `delete[]` operator.

```
delete[] ptr;
```

- If you allocate memory using the `new` operator (e.g. `new Cell`), you have to free it using the `delete` operator.

```
delete ptr;
```

- ***Make sure to use the proper deletion operation***. Mixing these up is like walking off the end of an array or using an uninitialized pointer; it *might* work, or it might instantly crash your program, etc.

Cleaning Up Memory

- To free a linked list, we can’t just do this:

```
delete list;
```

- Why not?

Cleaning Up Memory

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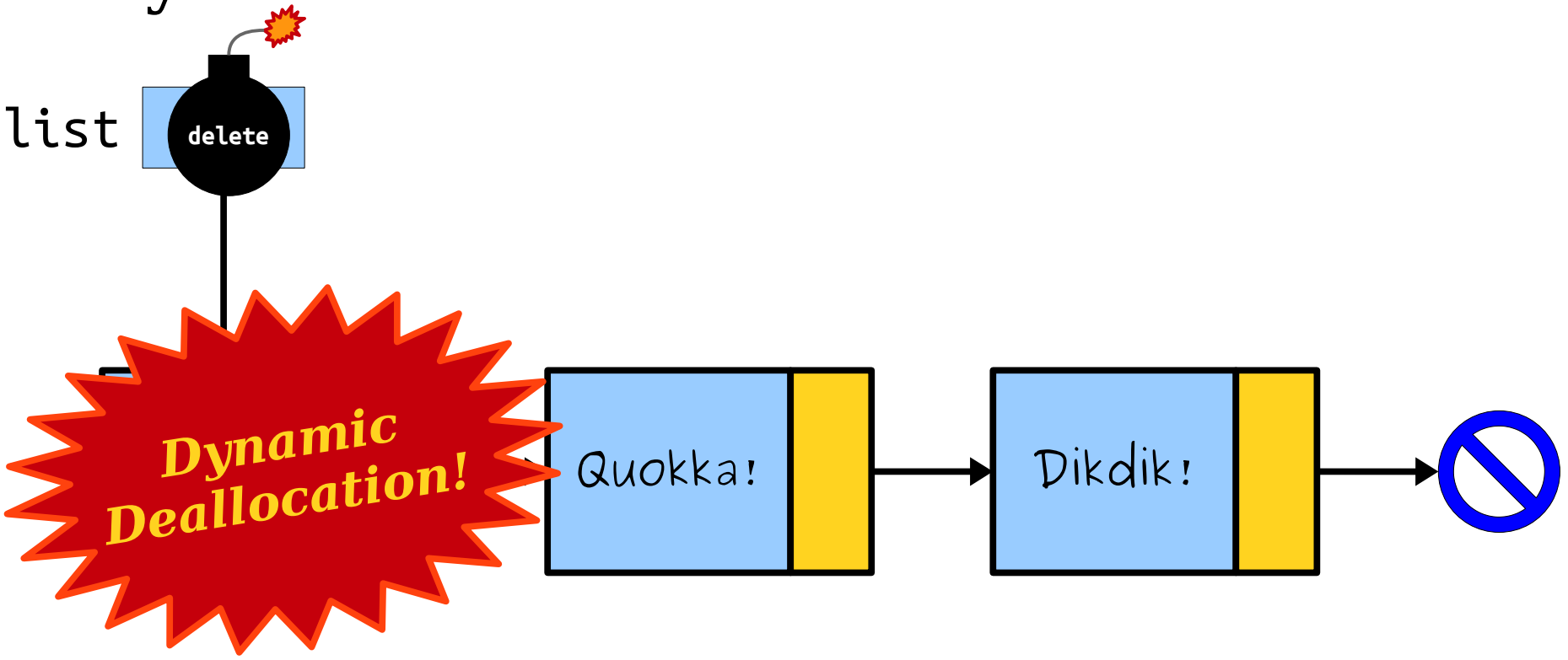

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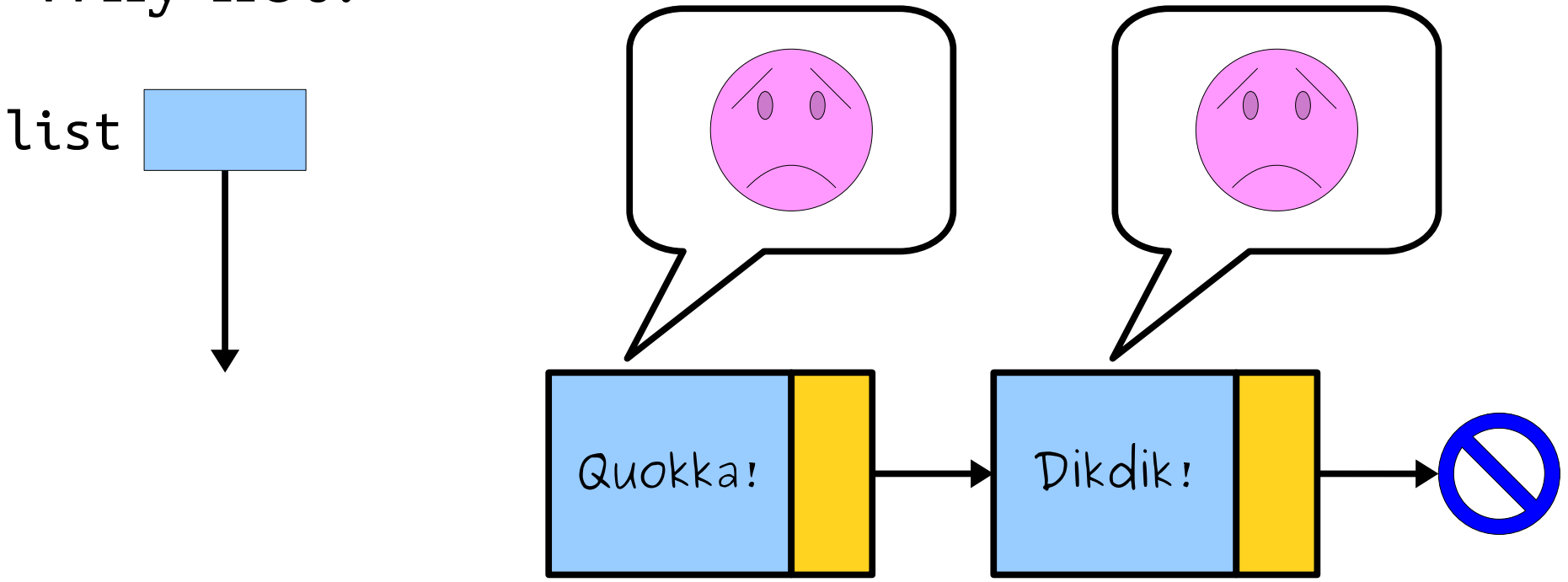
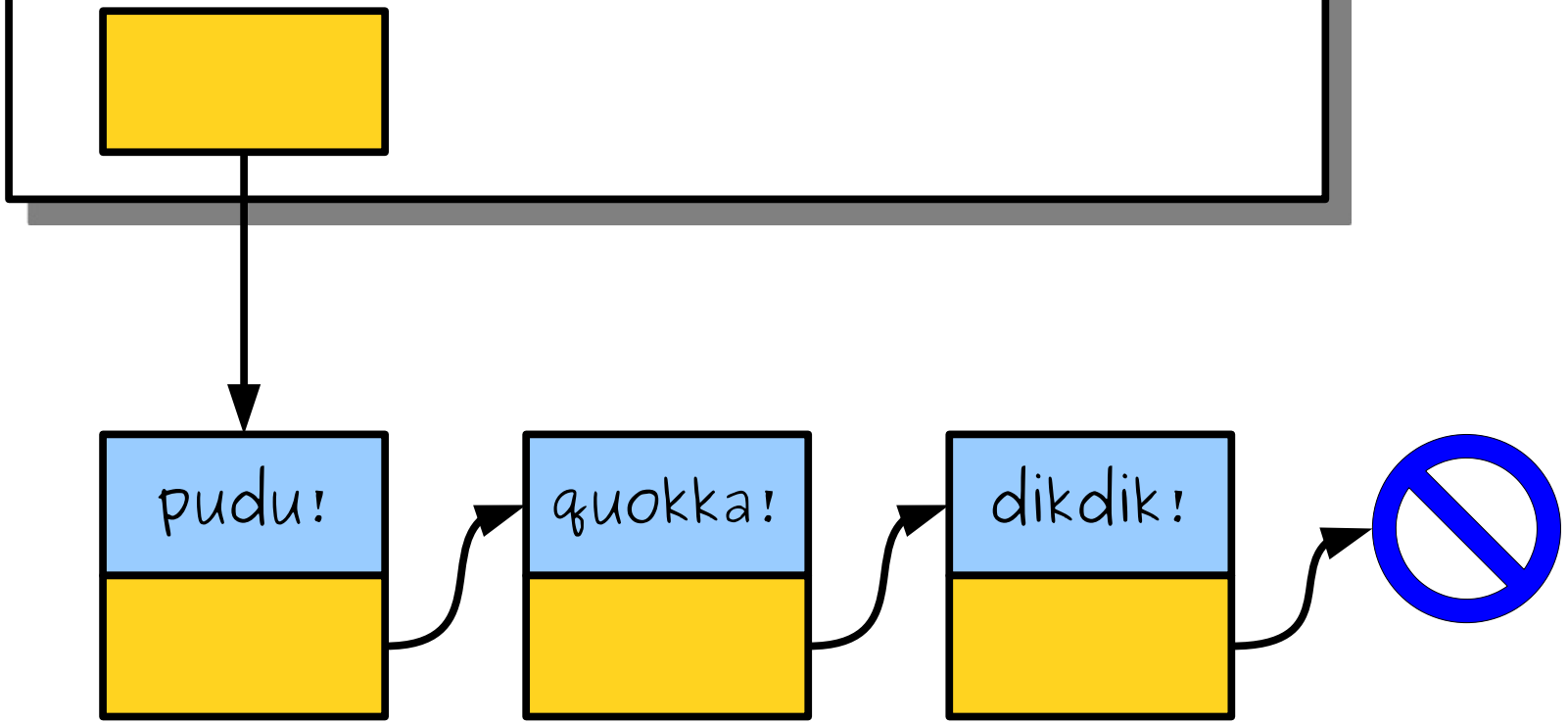


First, the Wrong Way

```
void deleteList(Cell* list) {
    // WRONG WRONG WRONG WRONG
    // WRONG WRONG WRONG WRONG

    while (list != nullptr) {
        delete list;
        list = list->next;
    }
}
```



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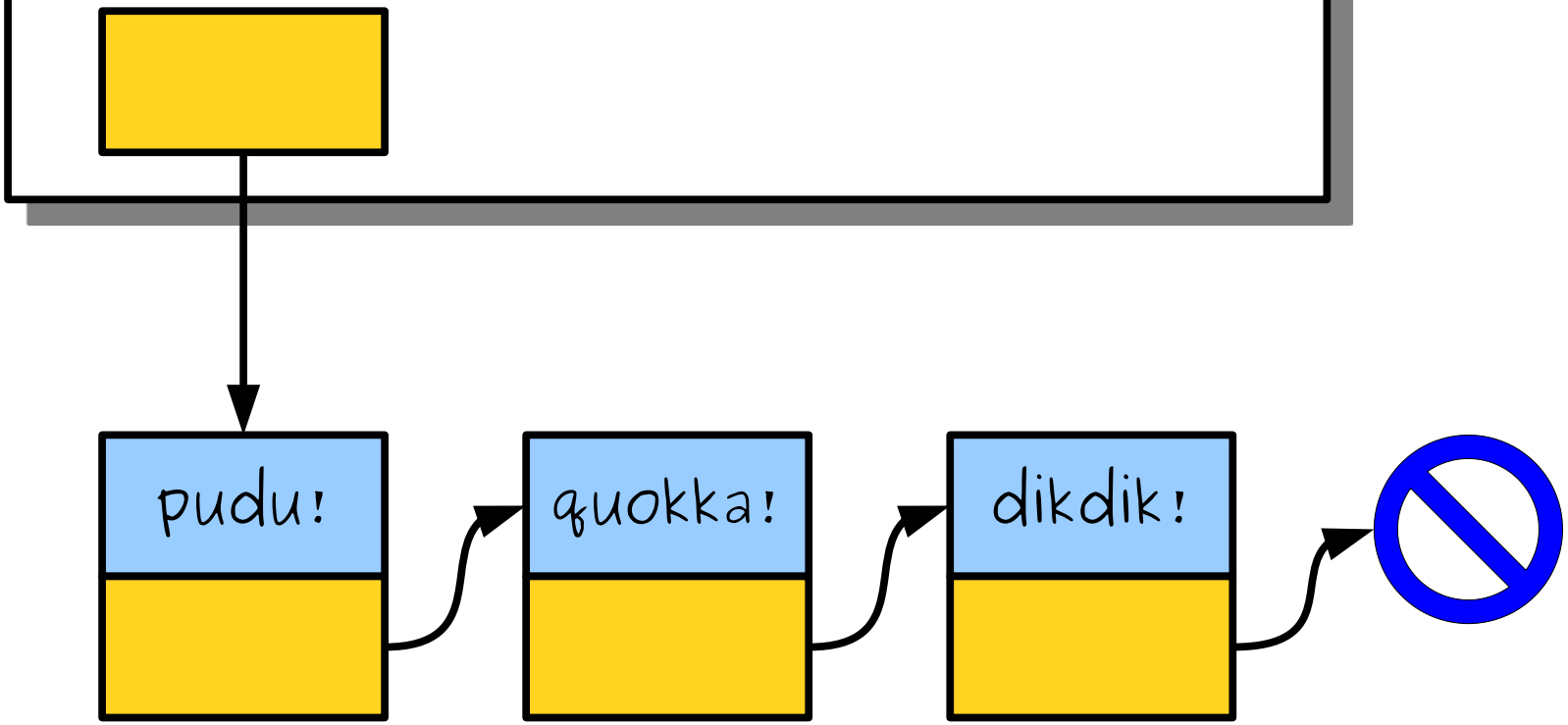

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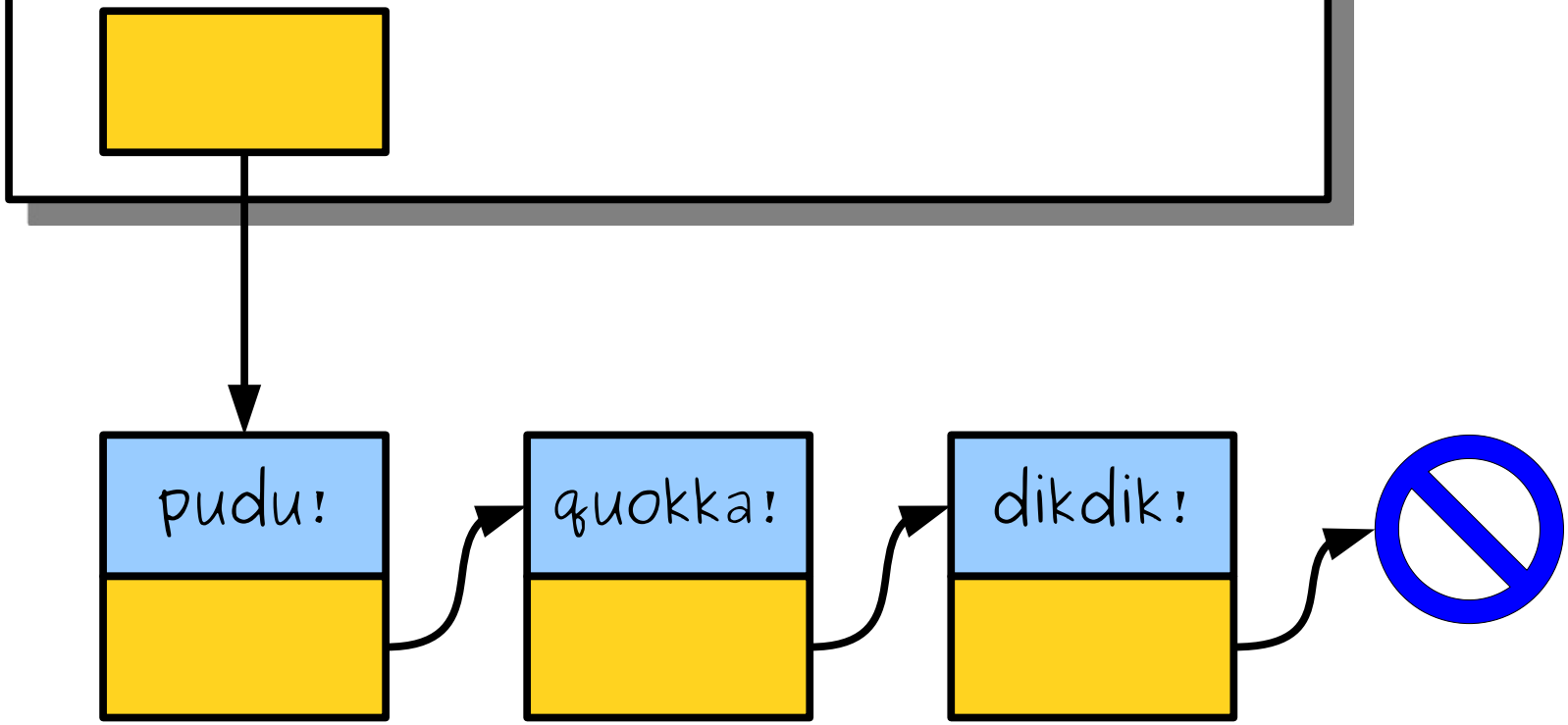

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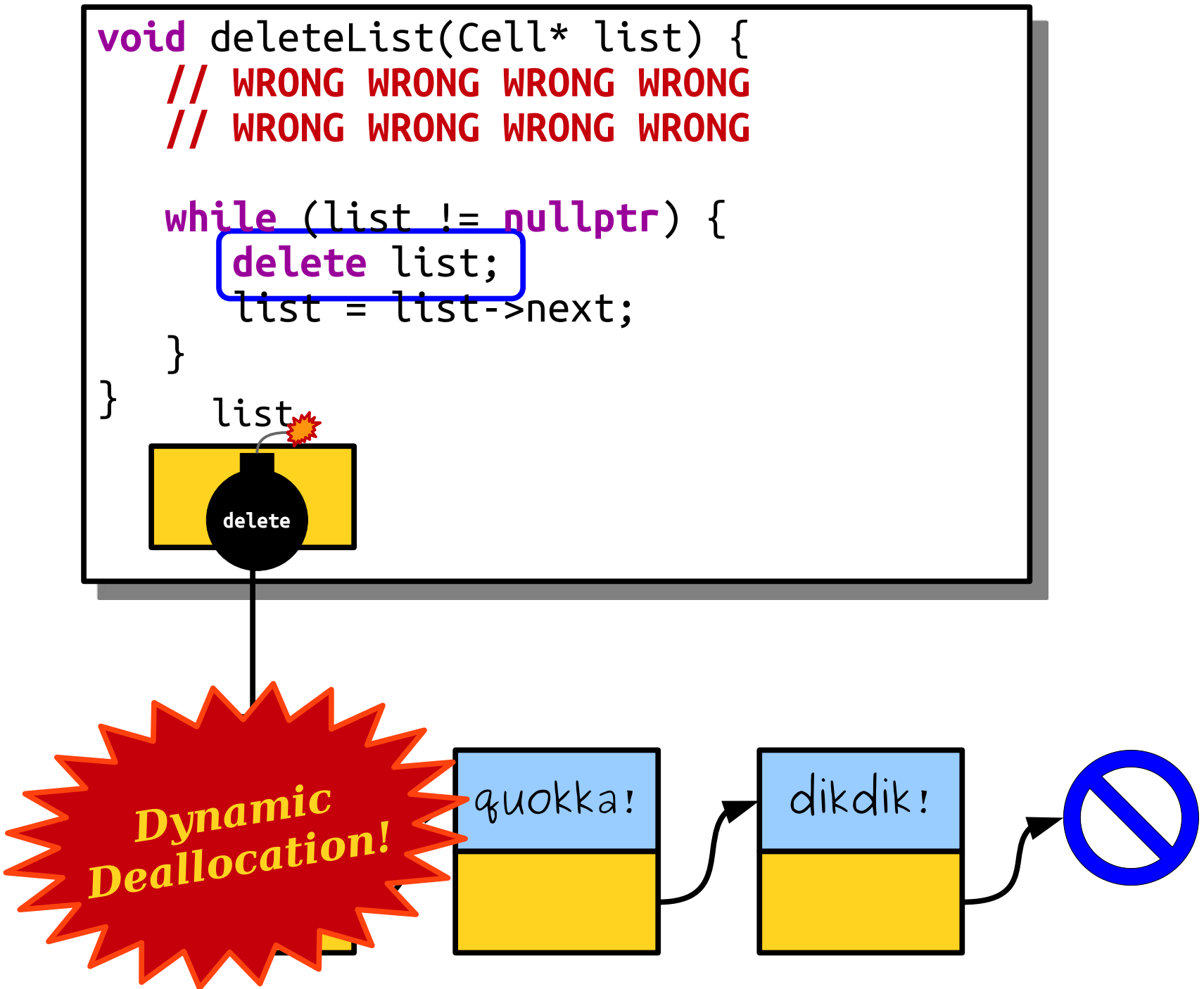

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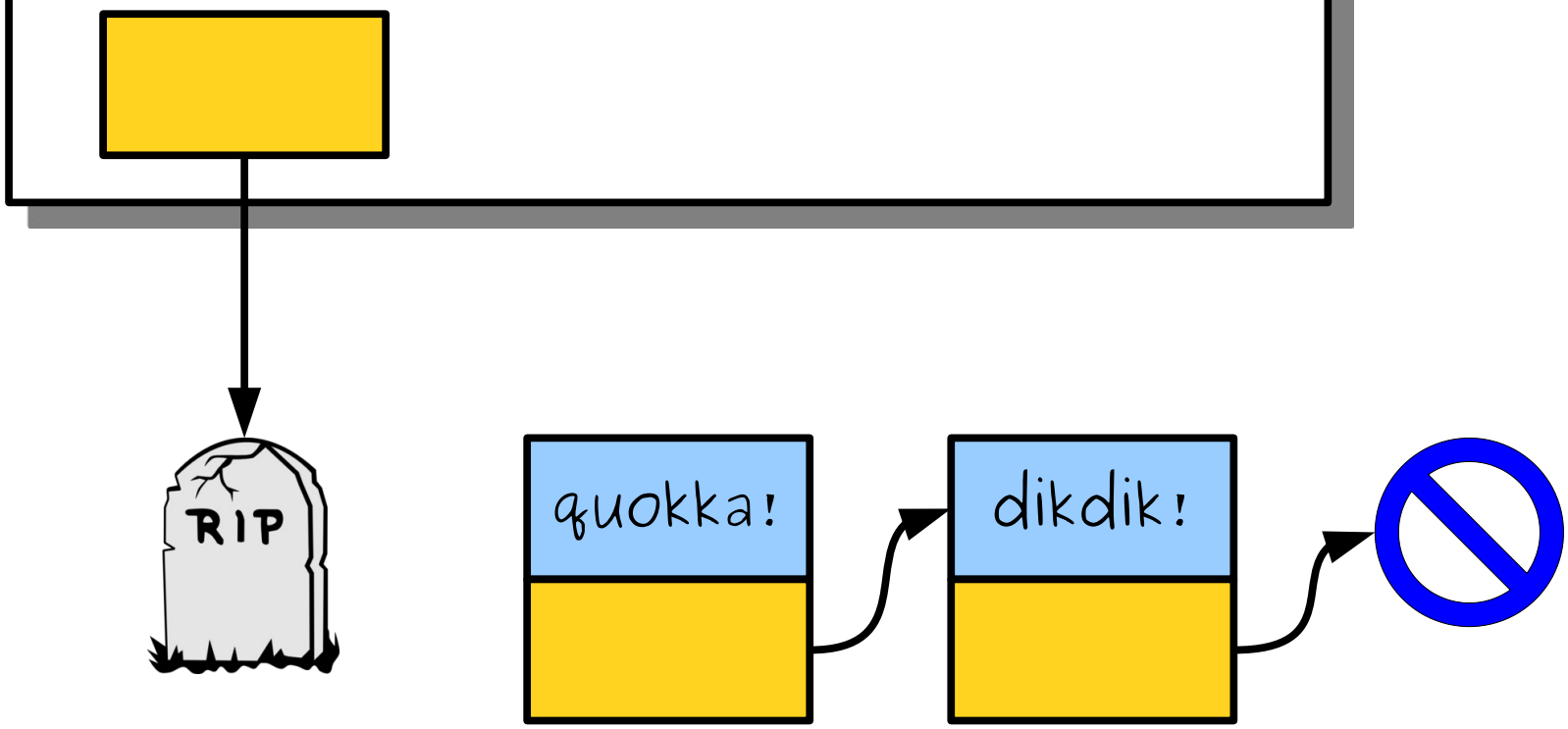

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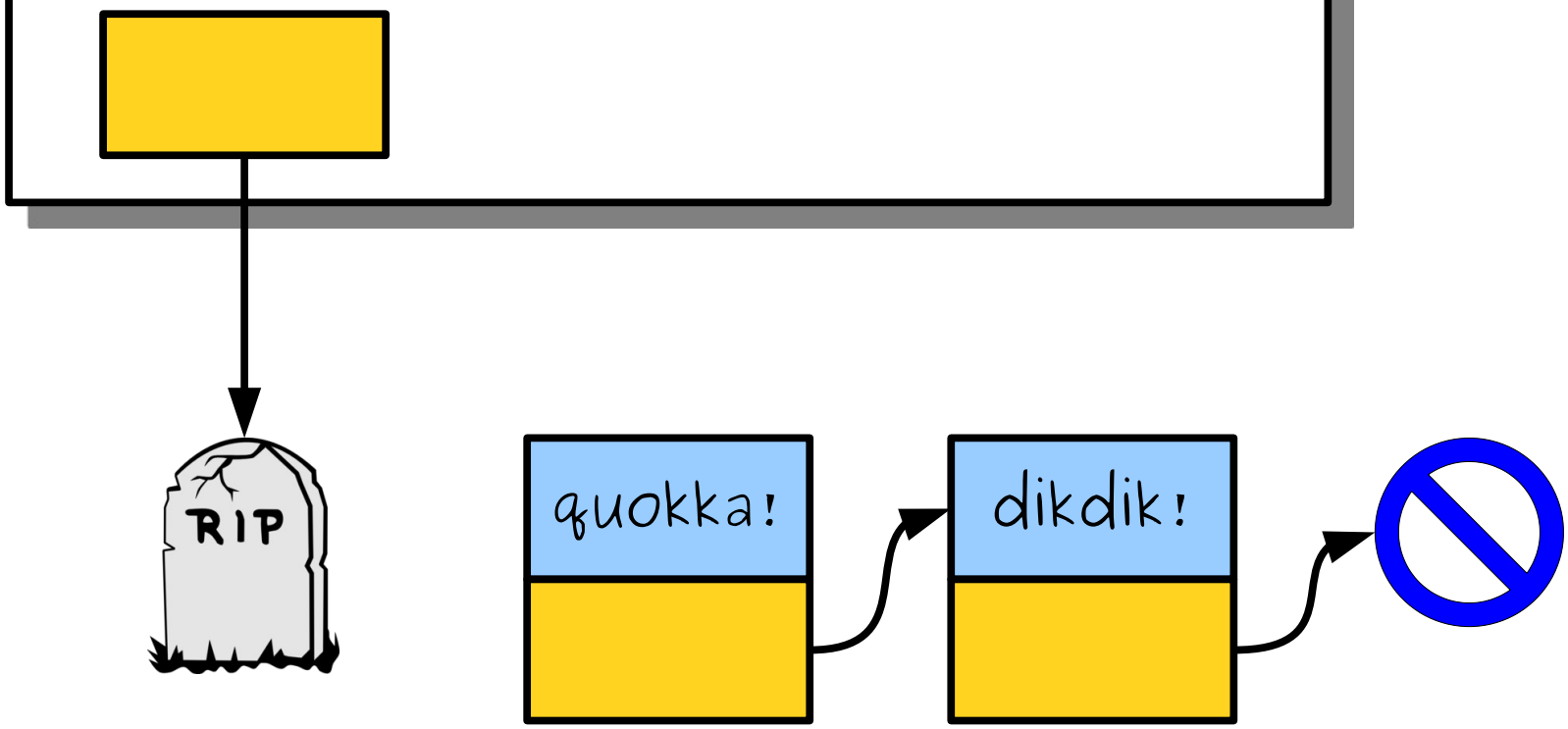
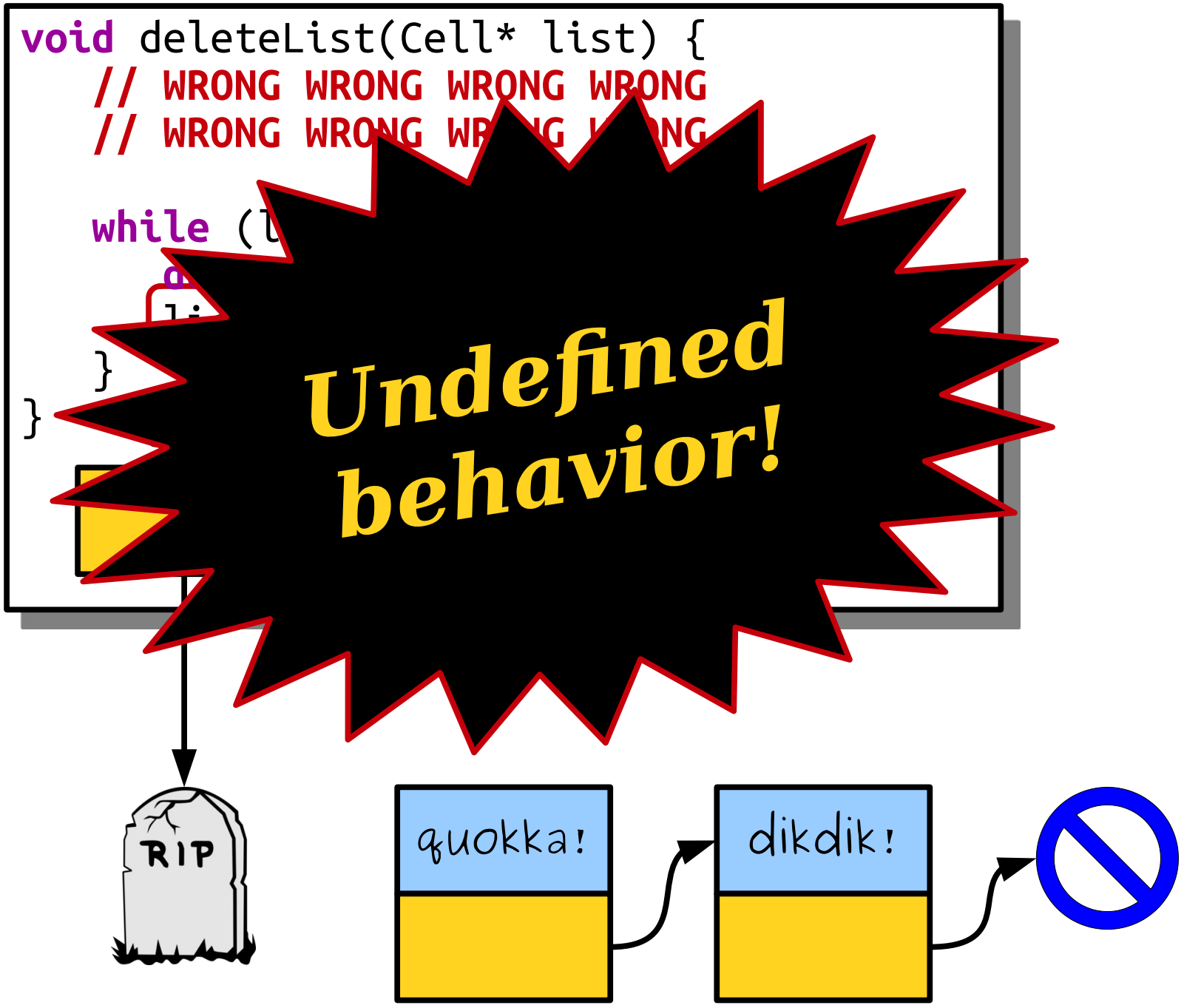


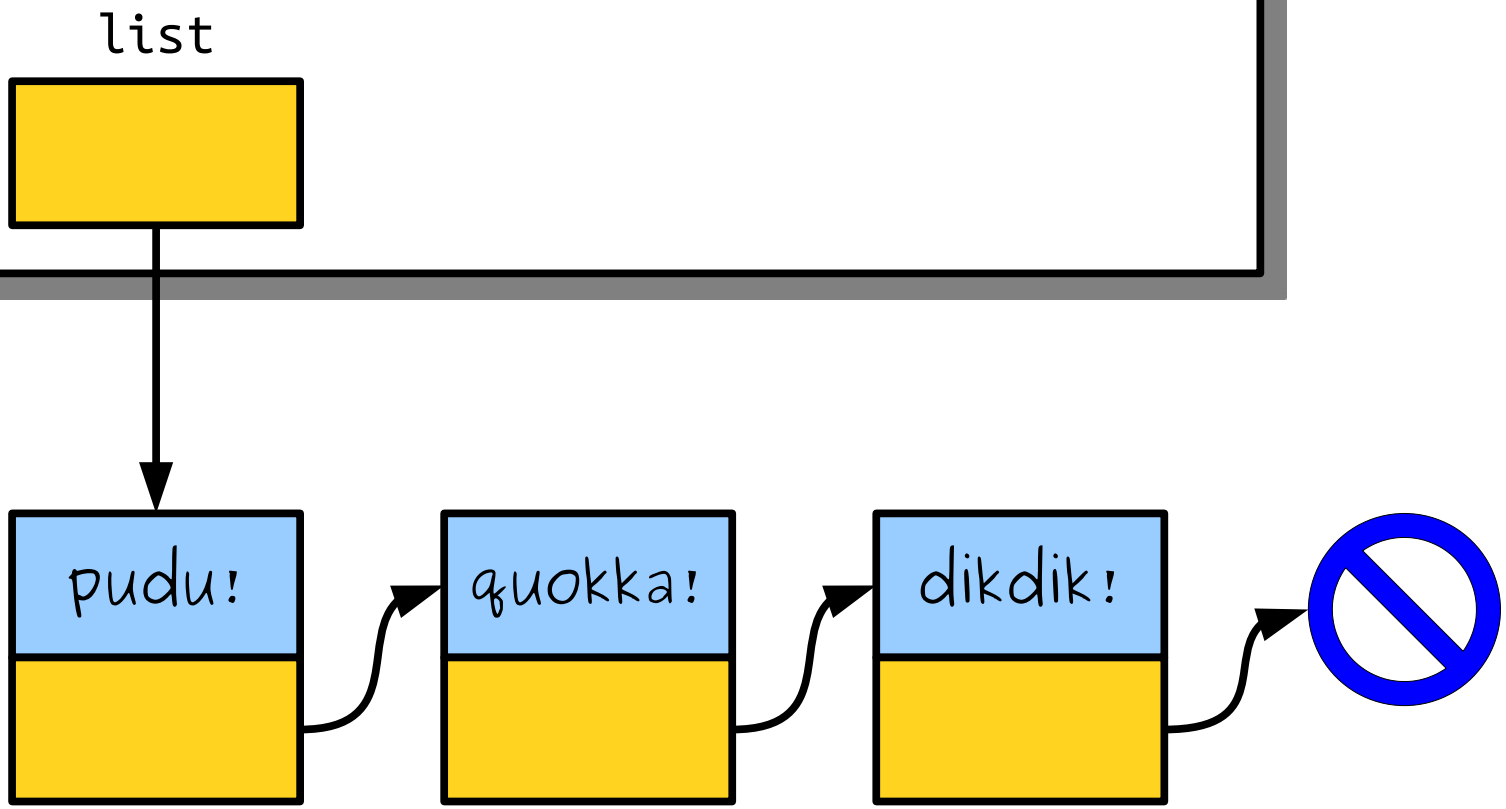

void deleteList(Cell* list) {
// WRONG WRONG WRONG WRONG
// WRONG WRONG WR NG NG
while (l
}
}
Undefined behavior!
RIP
quokka!
dikdik!

In the Land of C++, we
do not speak to the dead.

What should we do instead?

```
void deleteList(Cell* list) {
    while (list != nullptr) {

        delete list;
        list = list->next;
    }
}
```



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    while (list != nullptr) {
        Cell* next = list->next;
        delete list;
        list = list->next;
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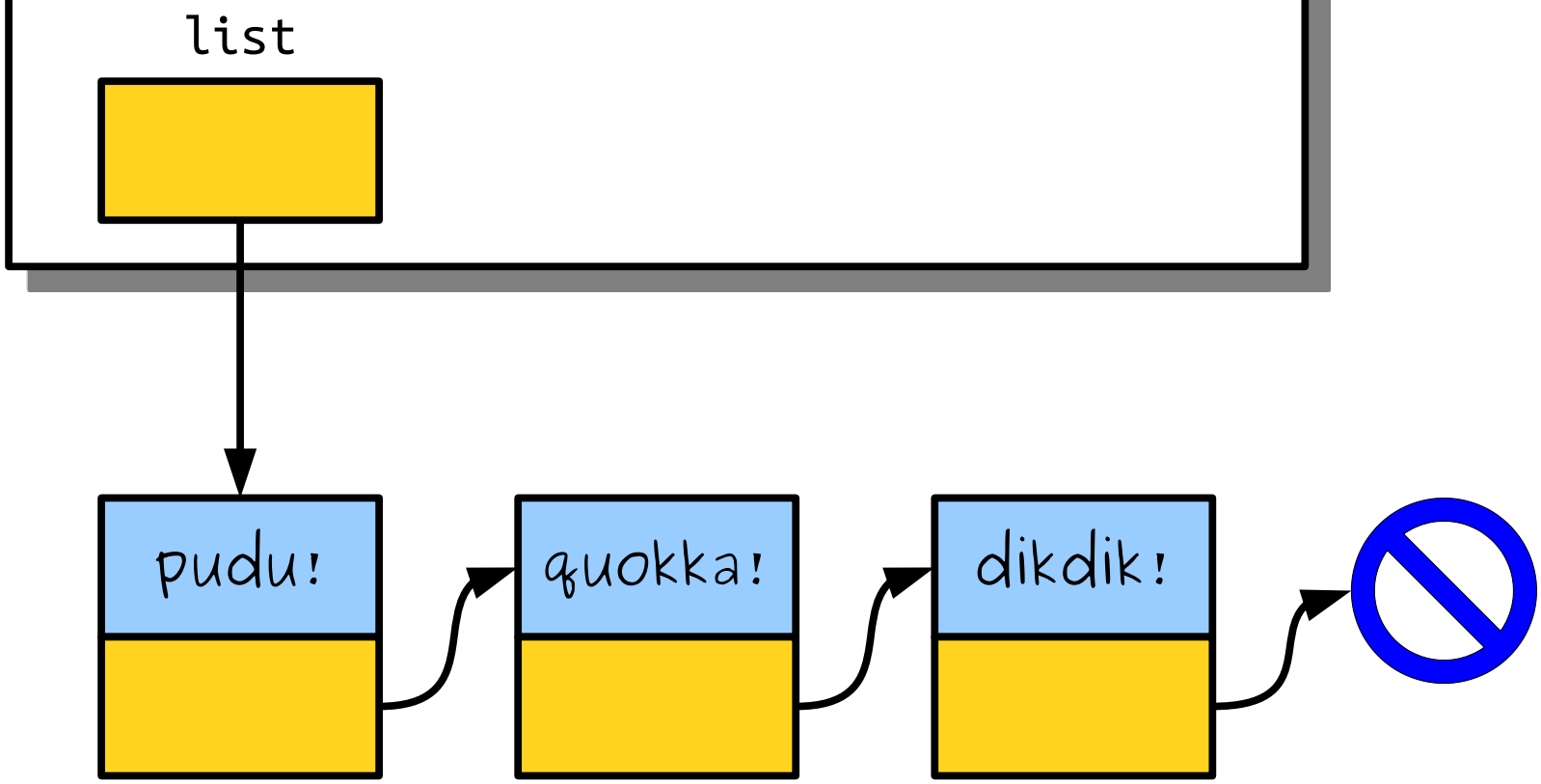

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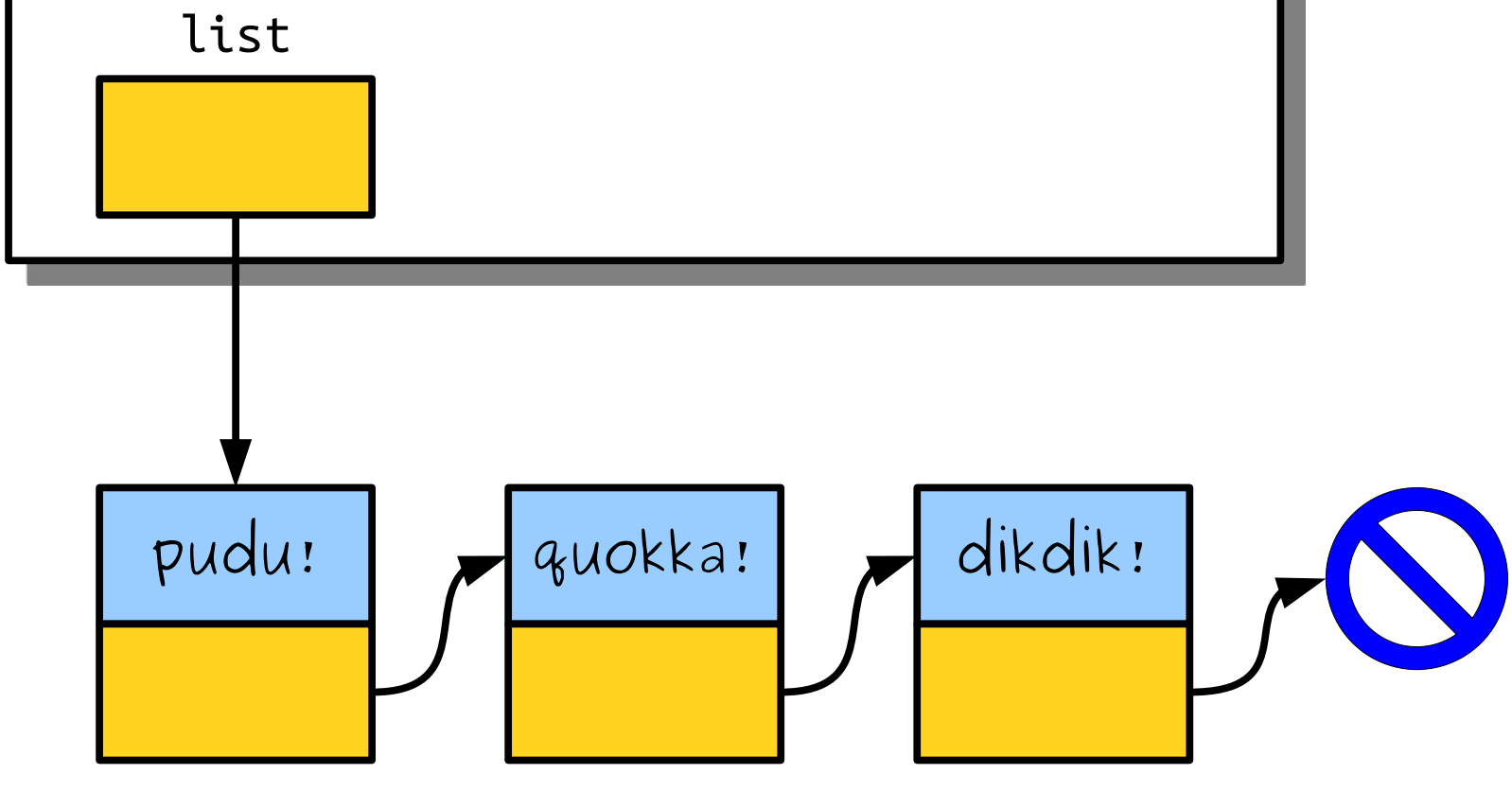

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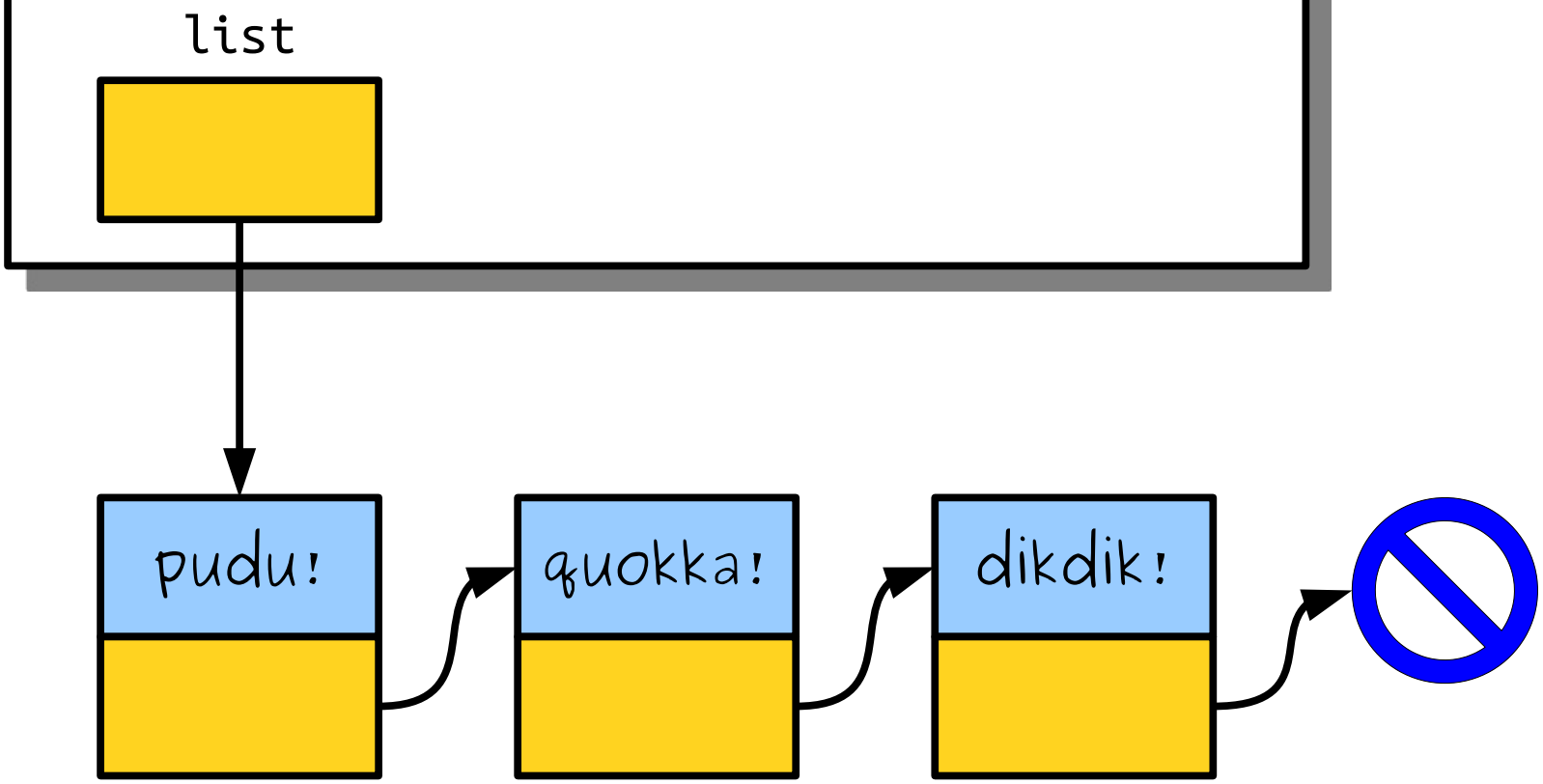

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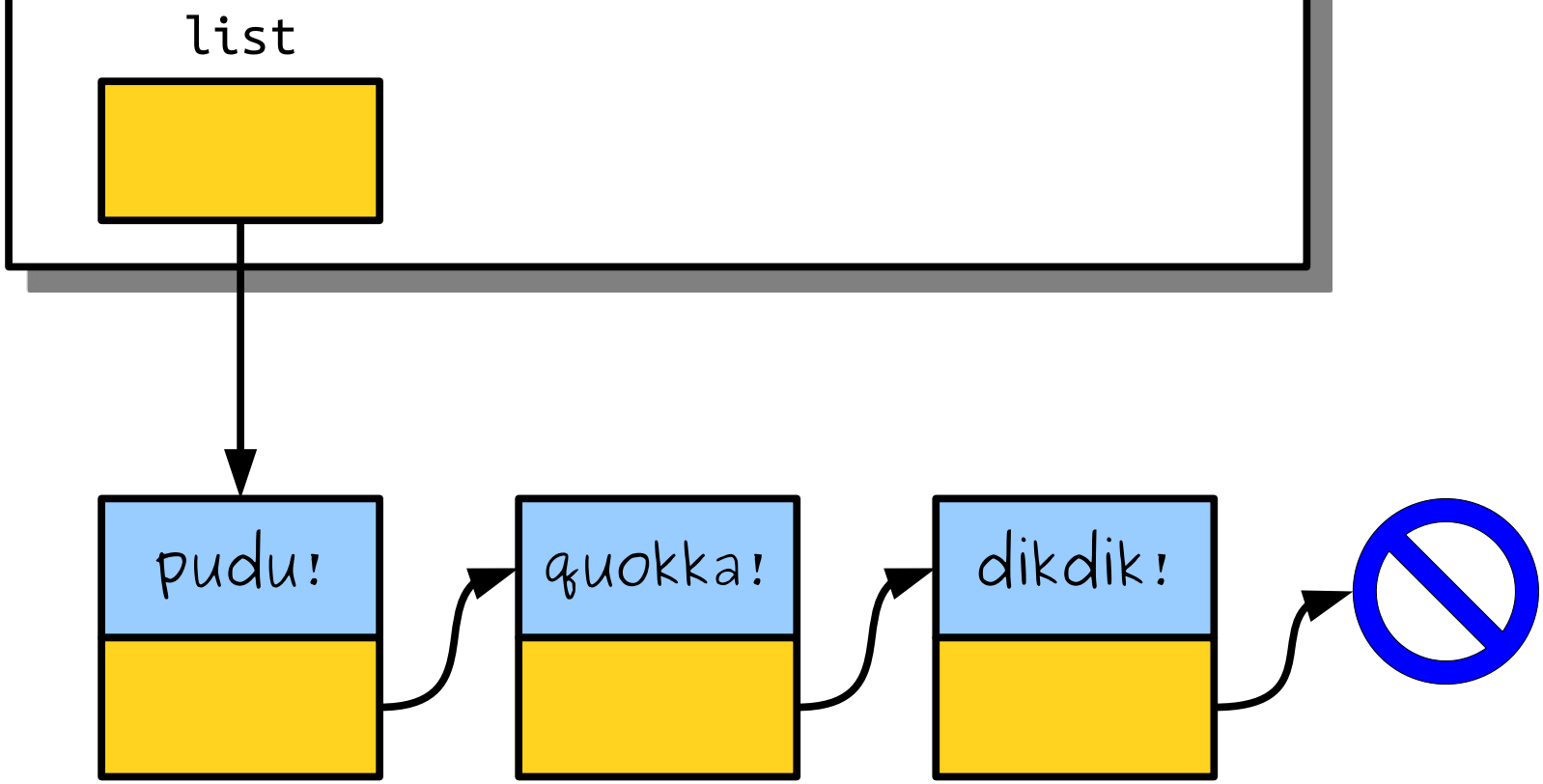

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        Cell* next = list->next;
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}
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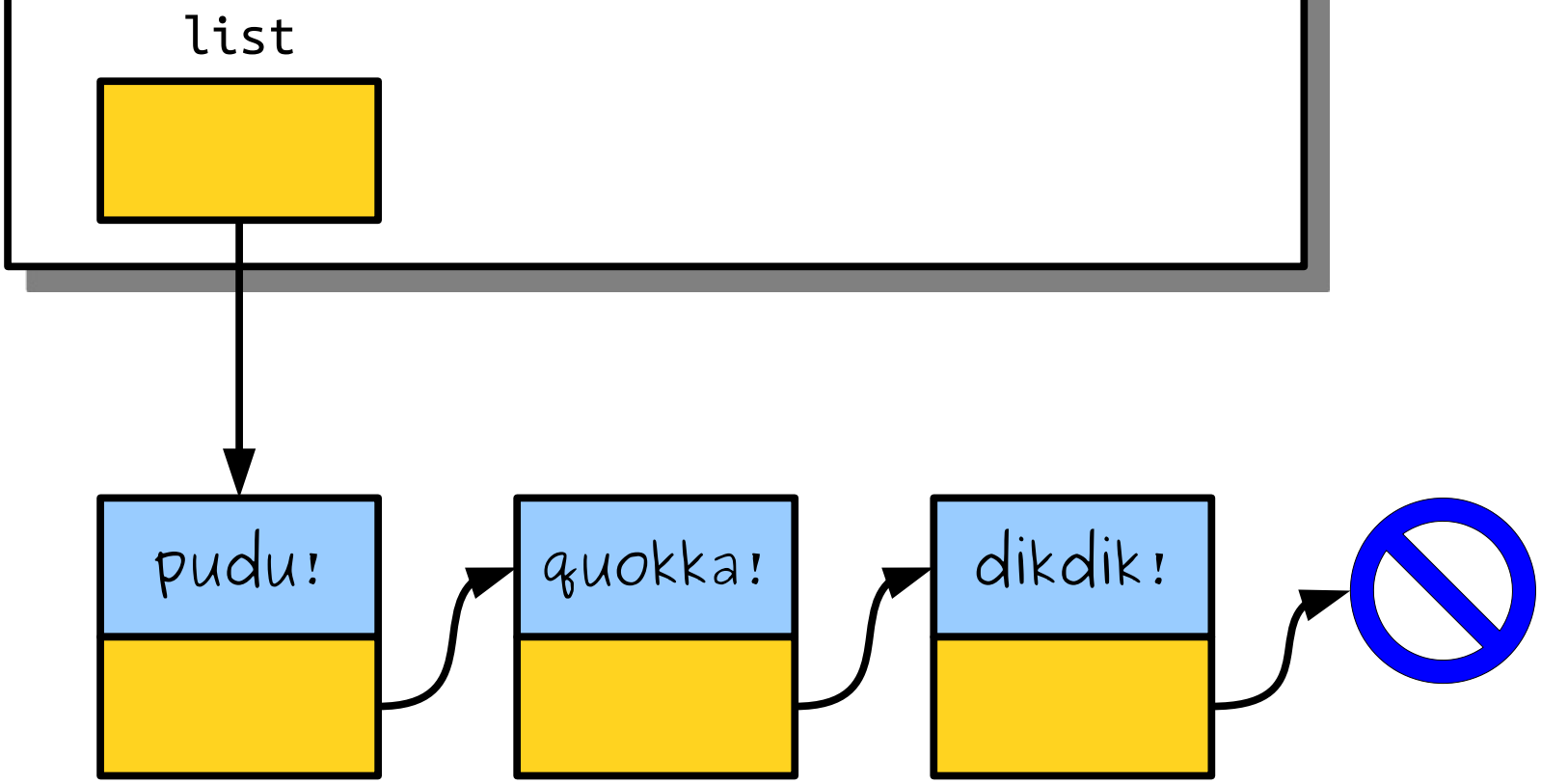

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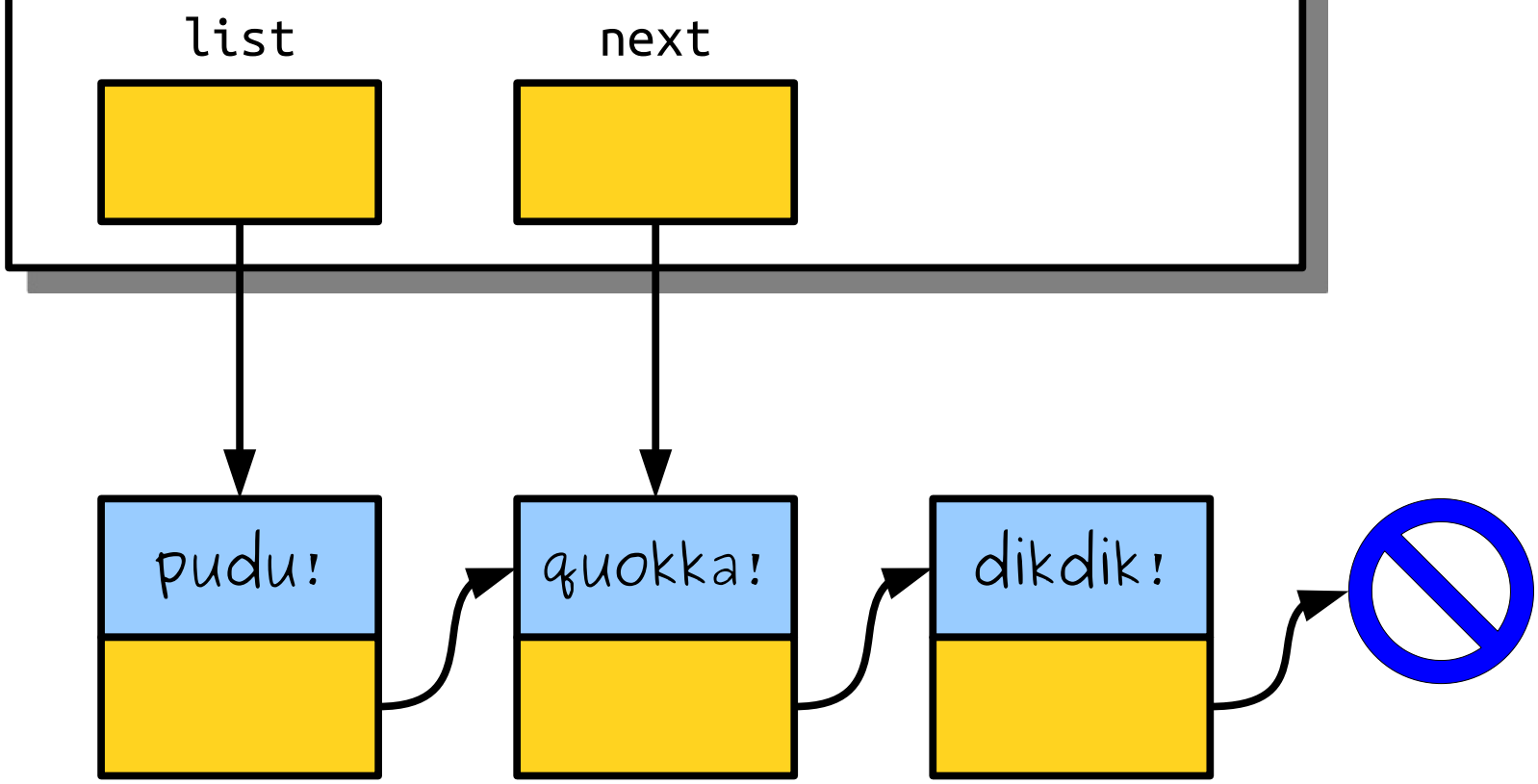

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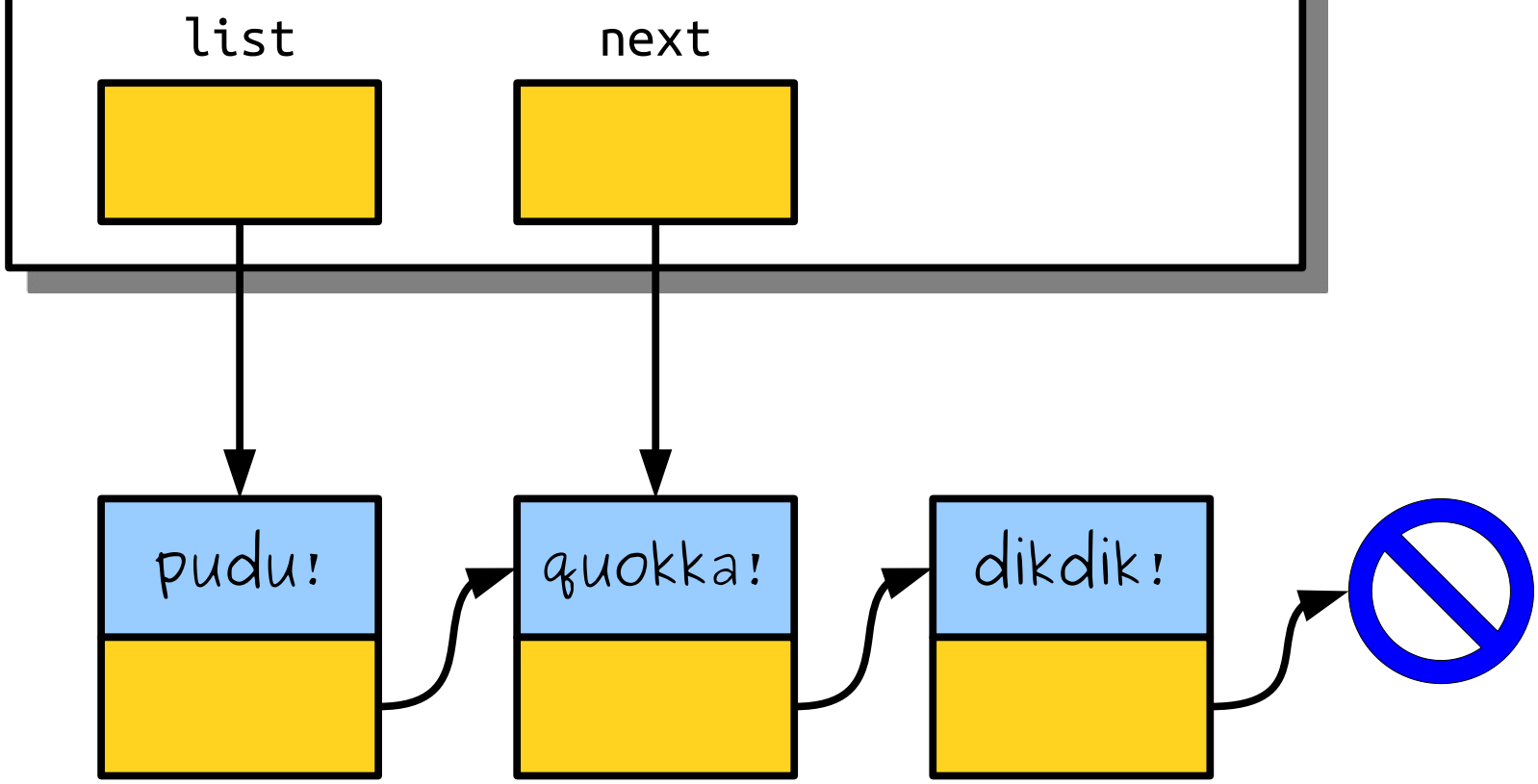

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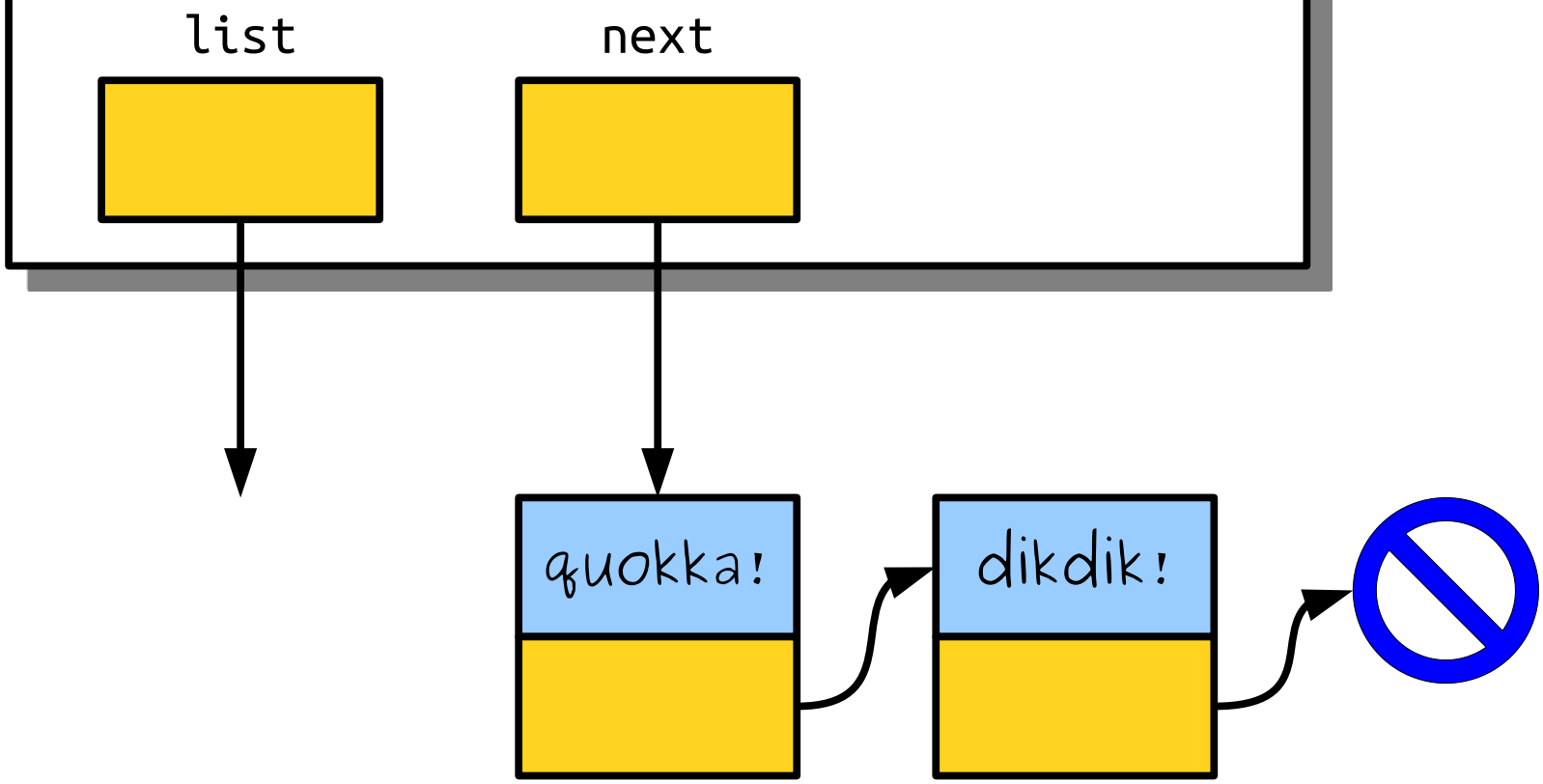

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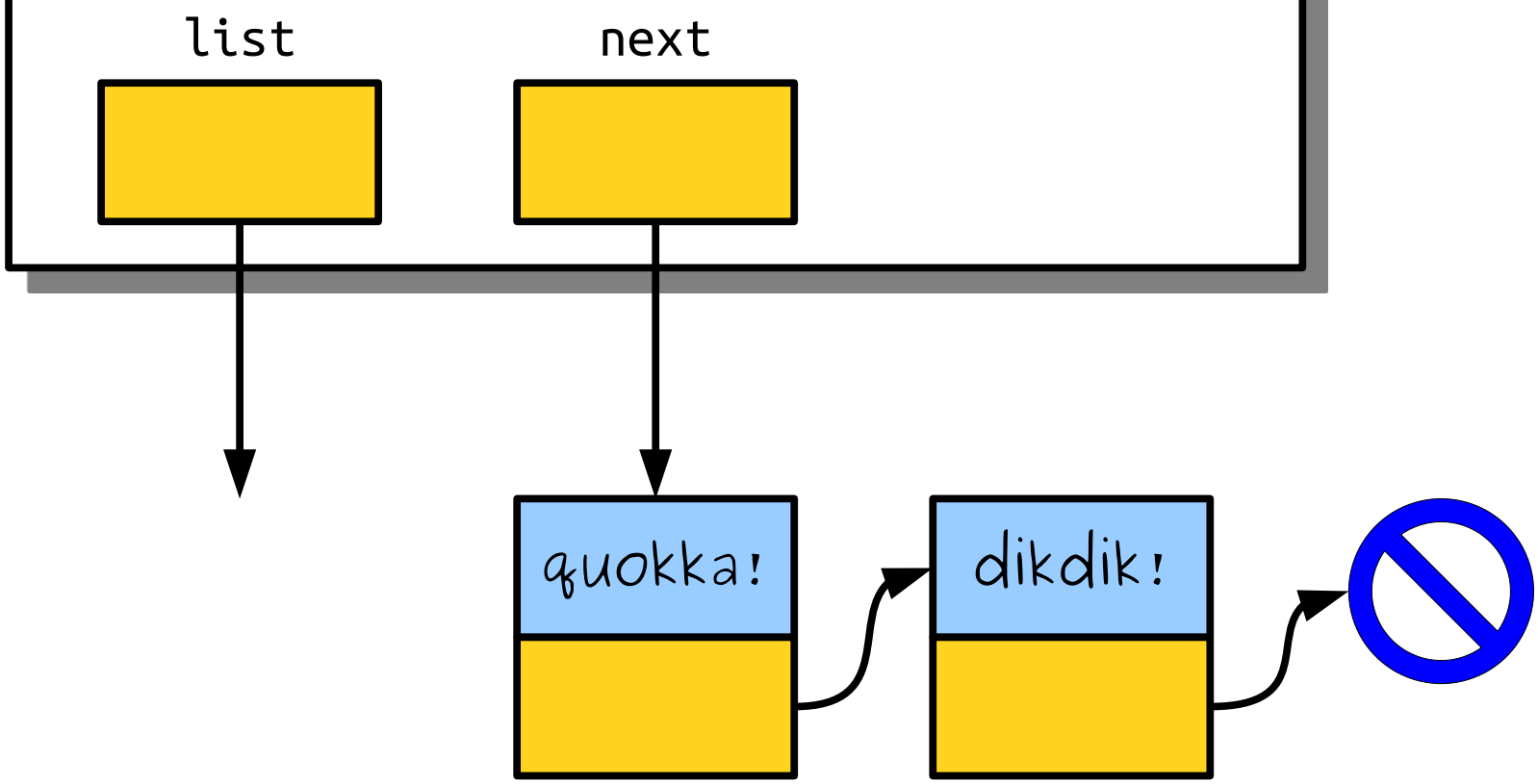

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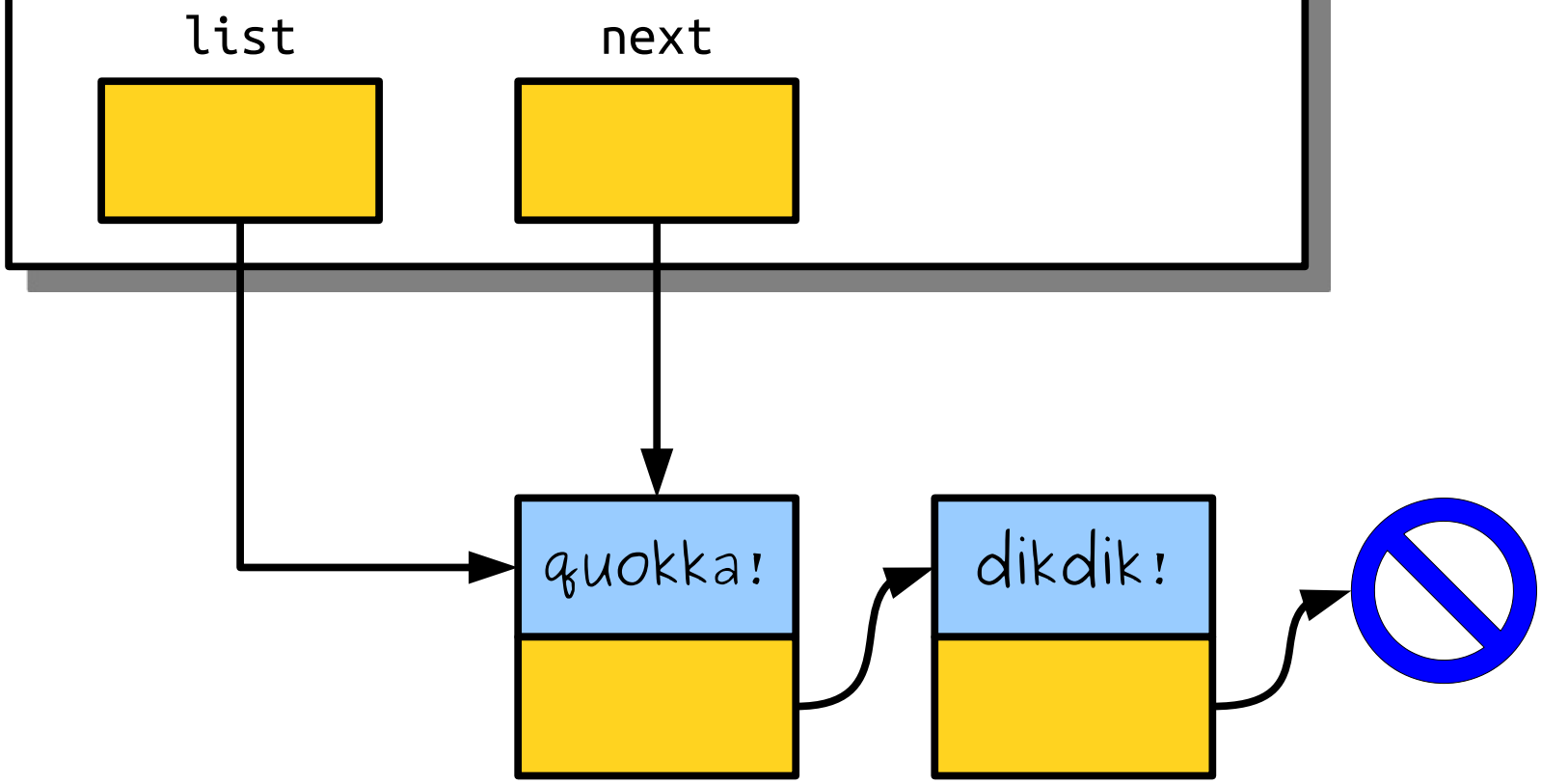

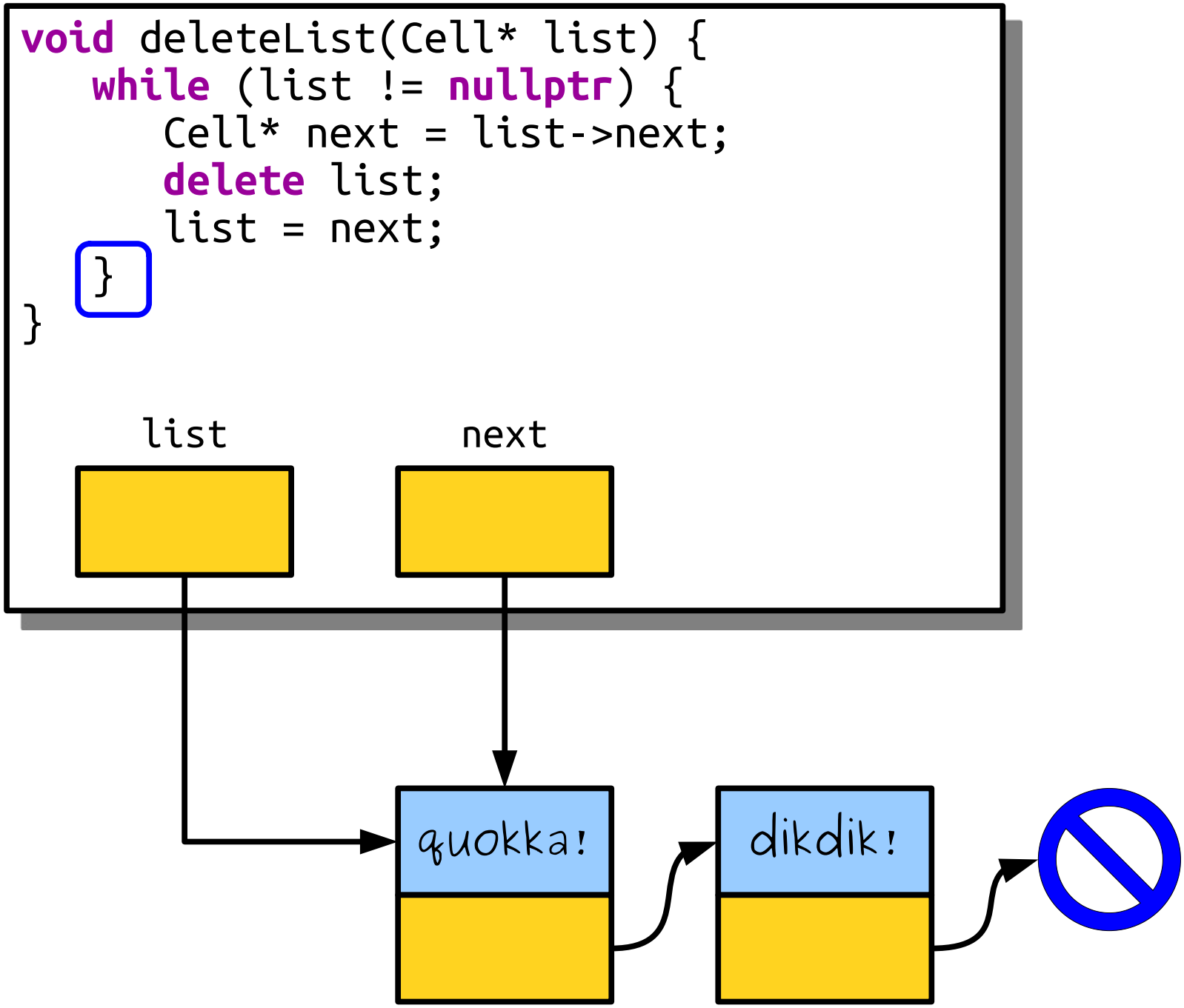
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delete list;
list = next;
}
}
list
next
quokka!
dikdik!

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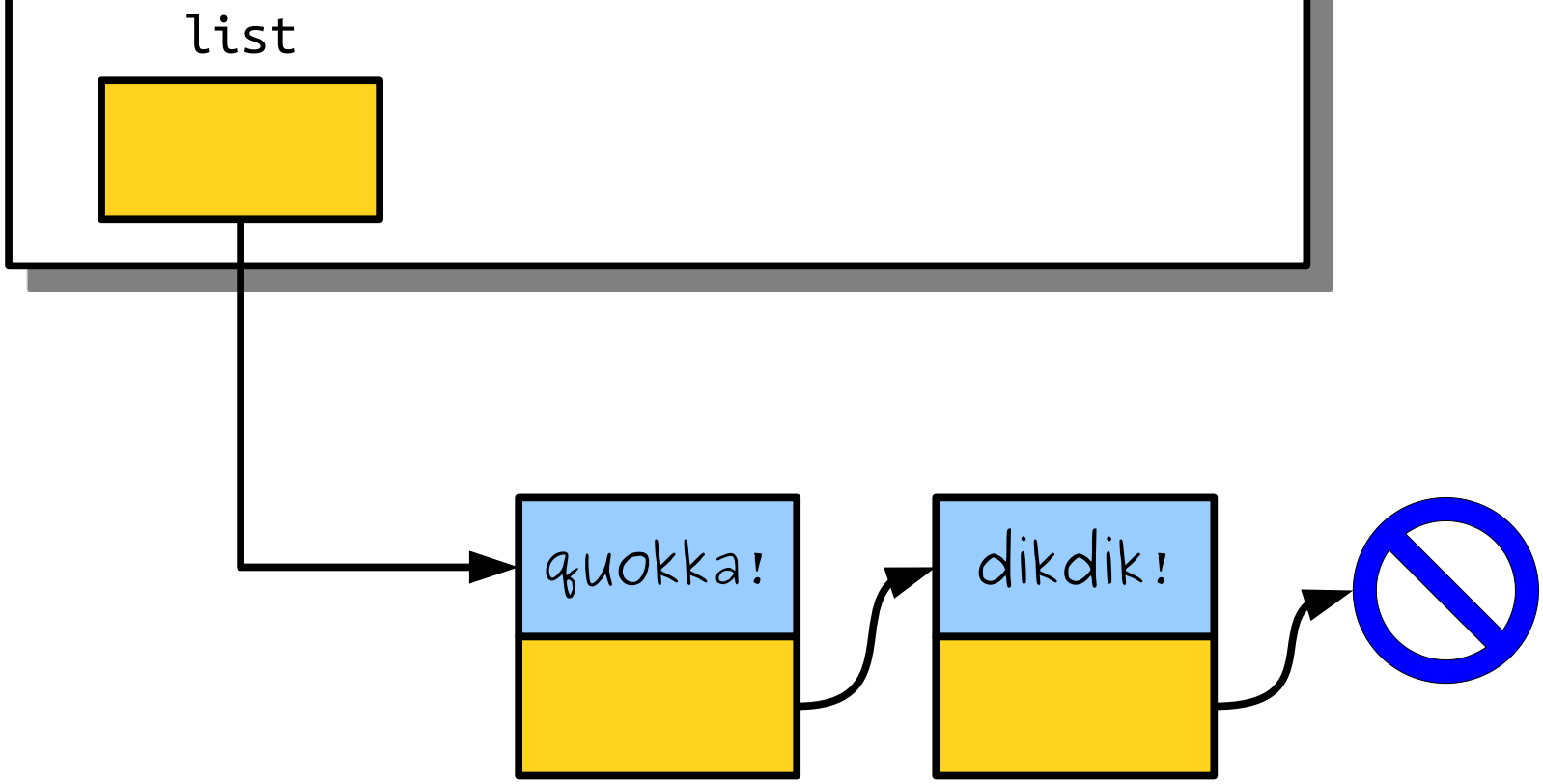

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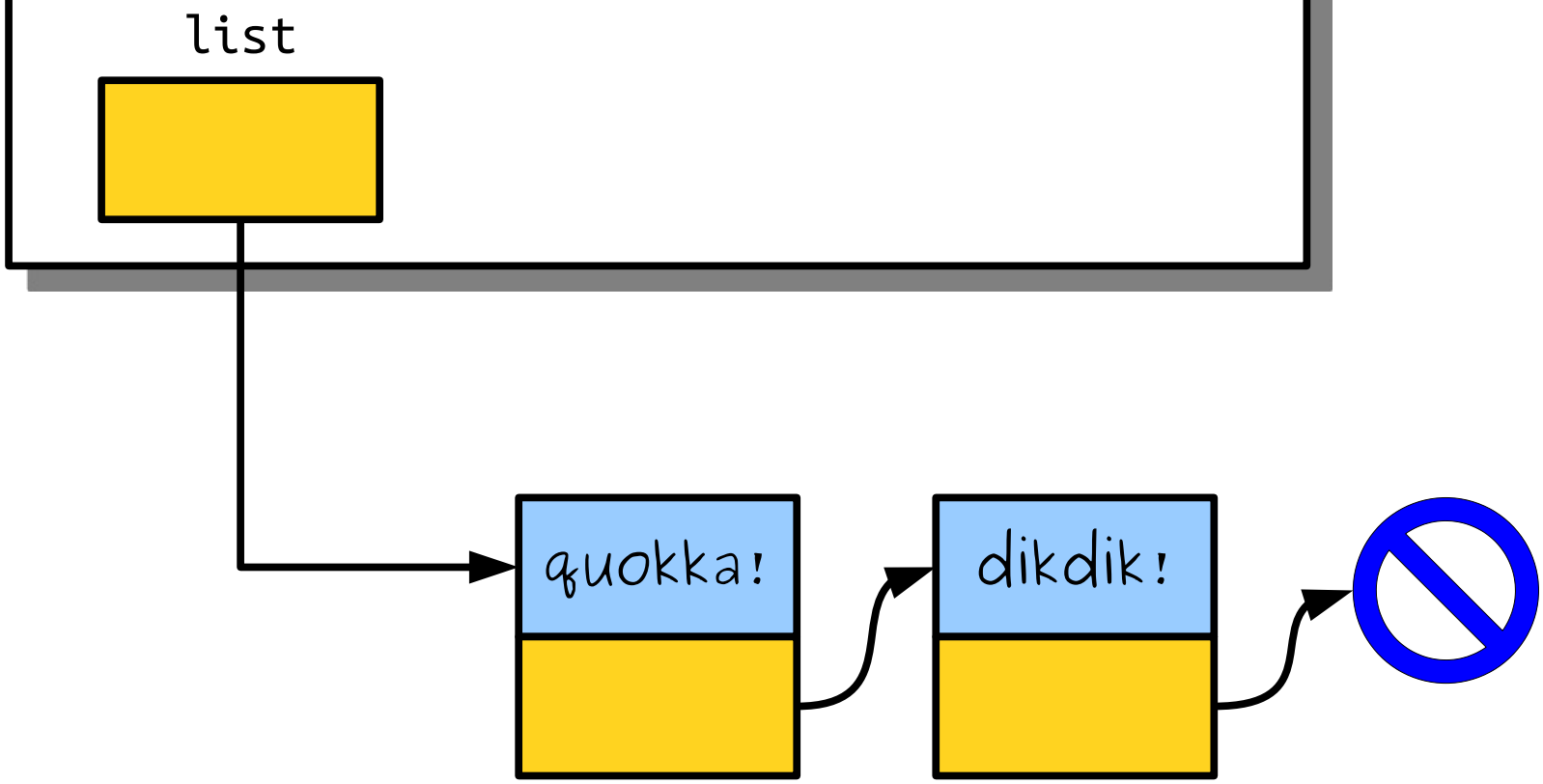

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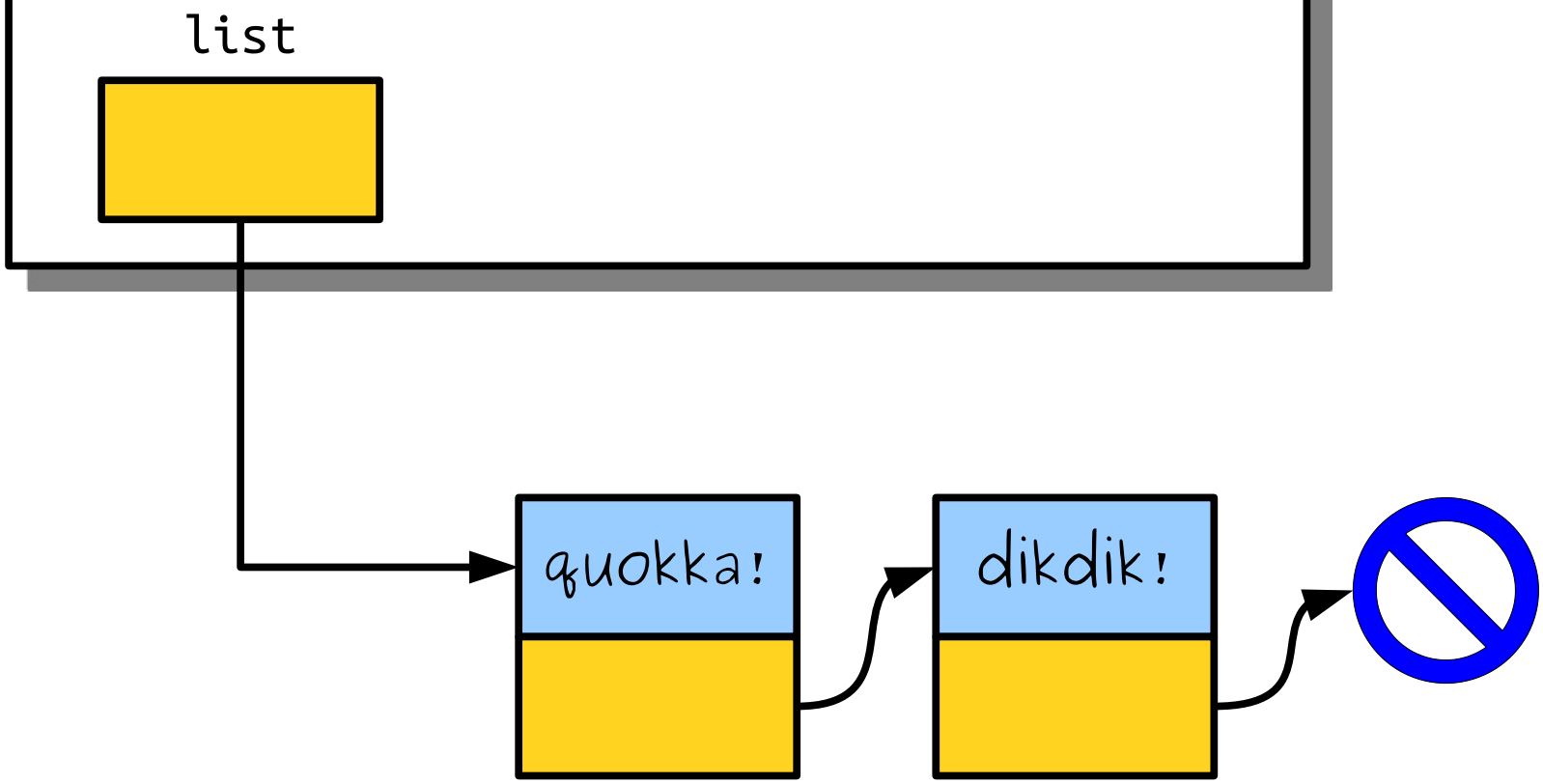

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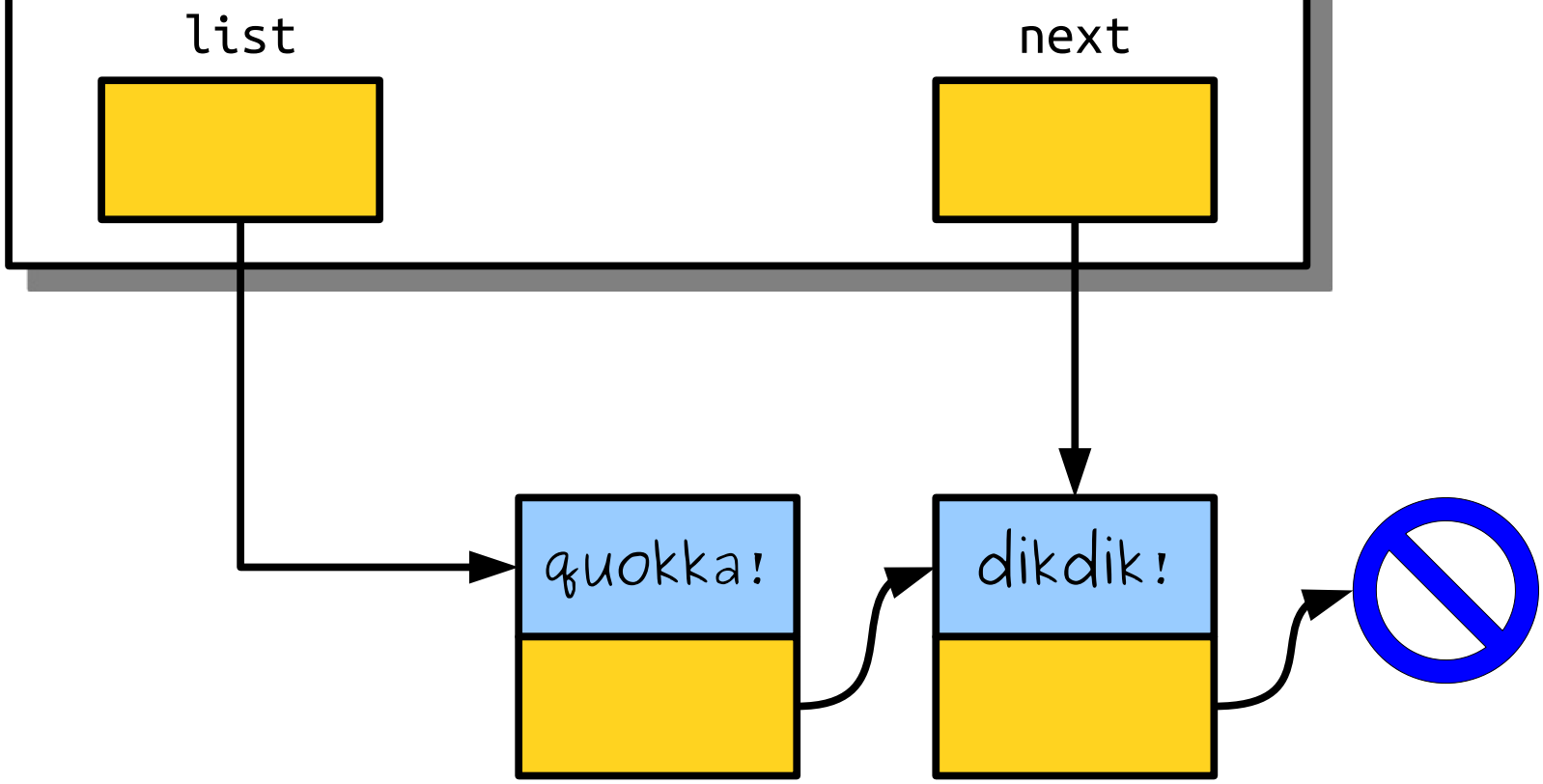

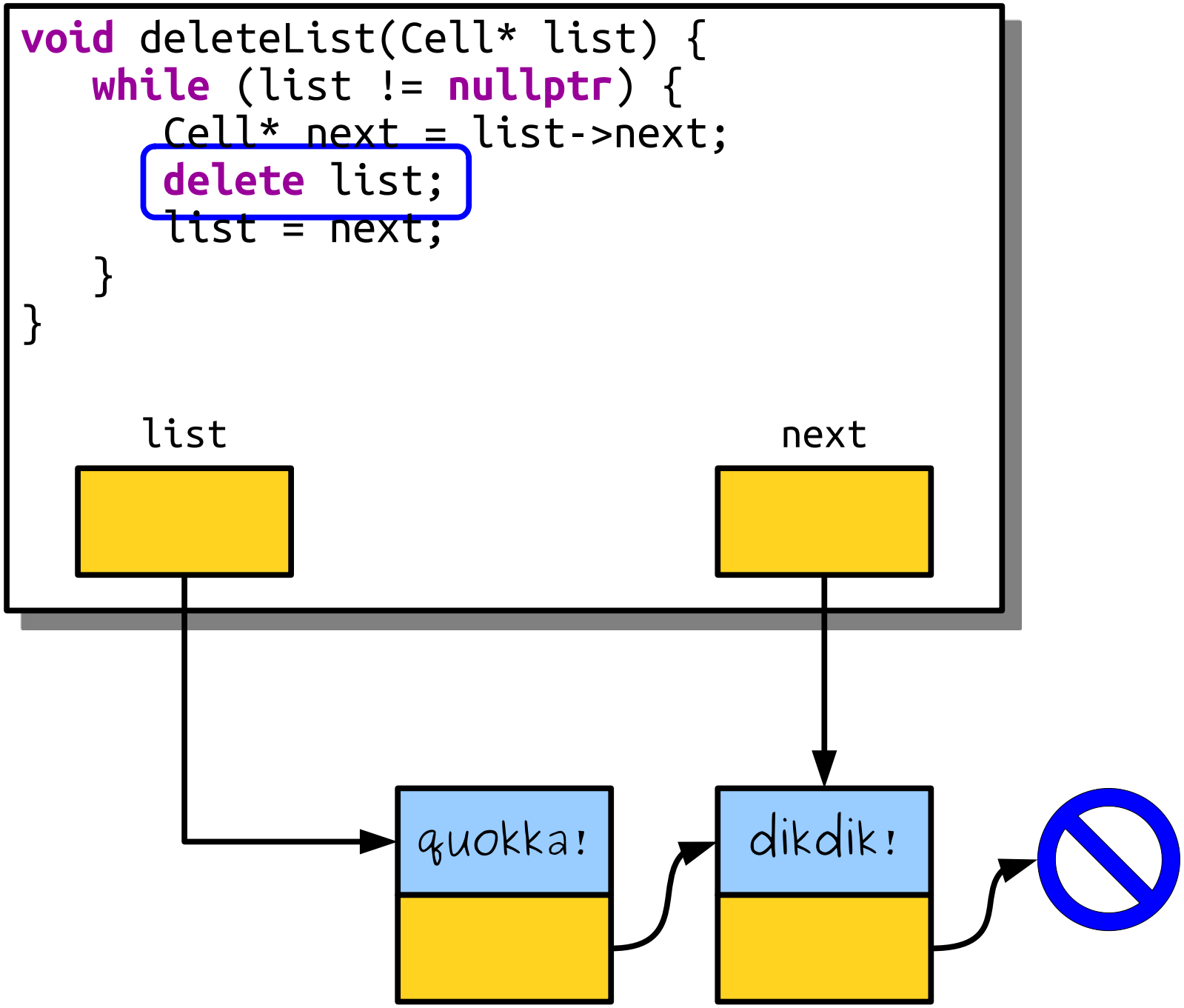
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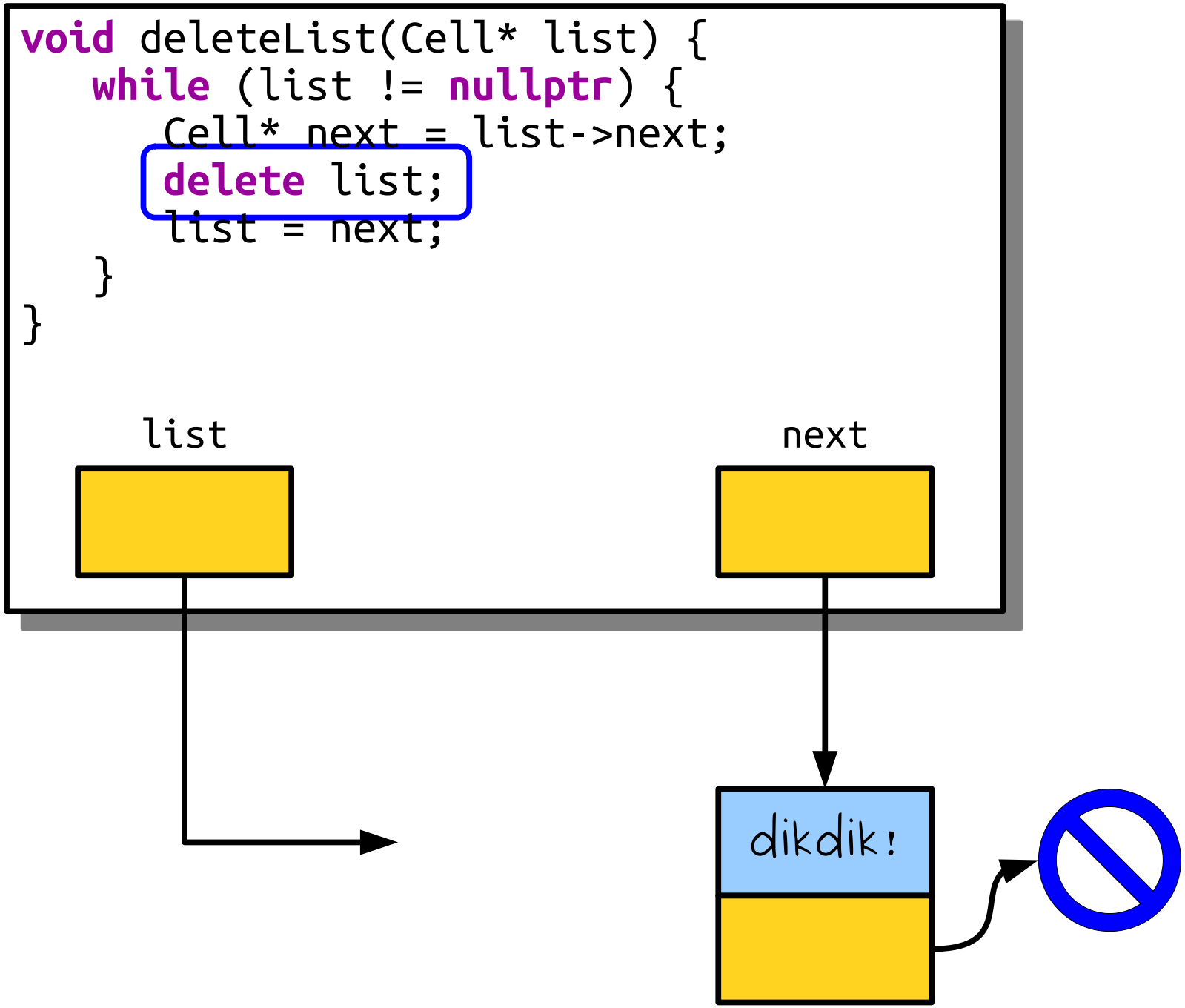
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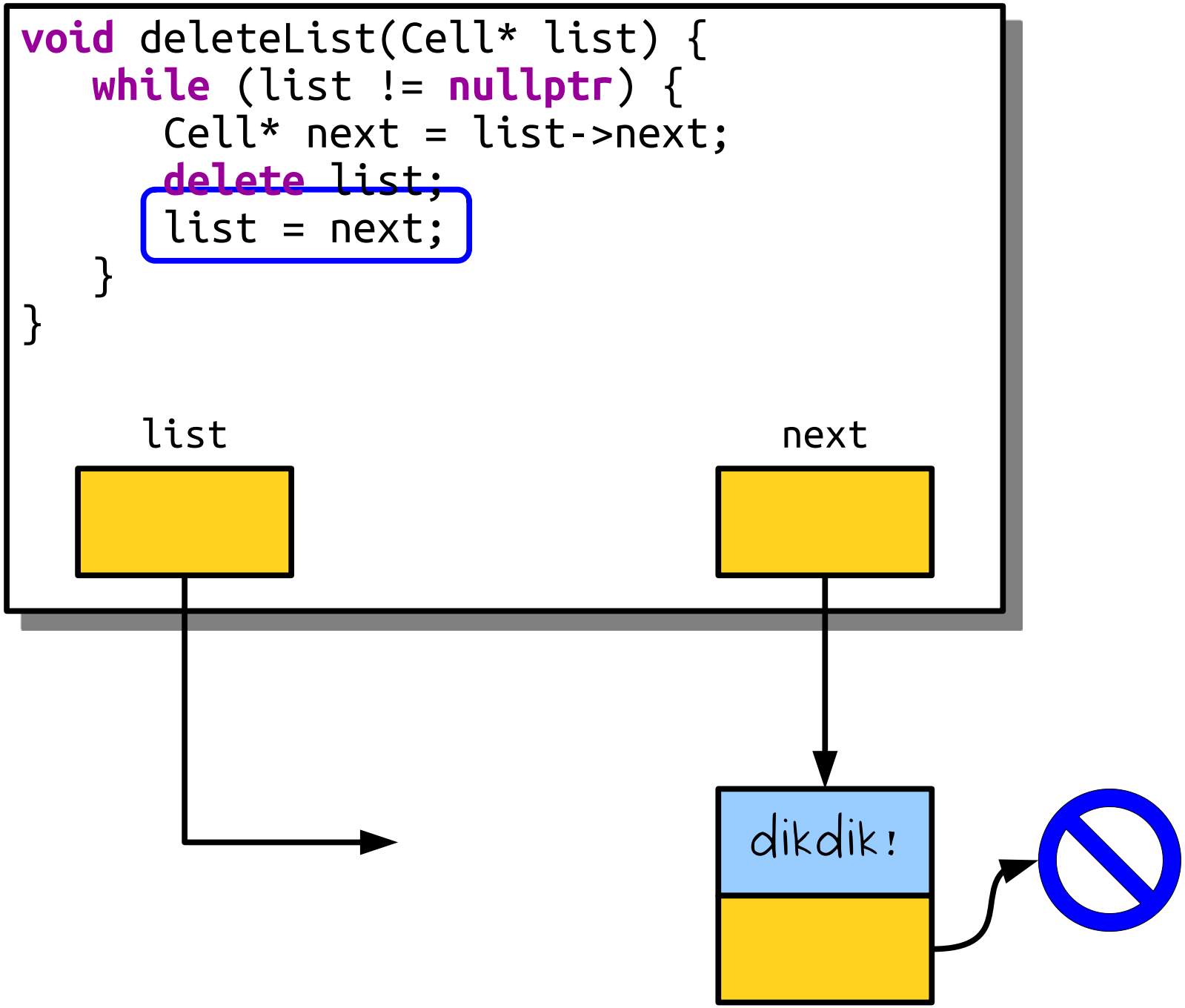
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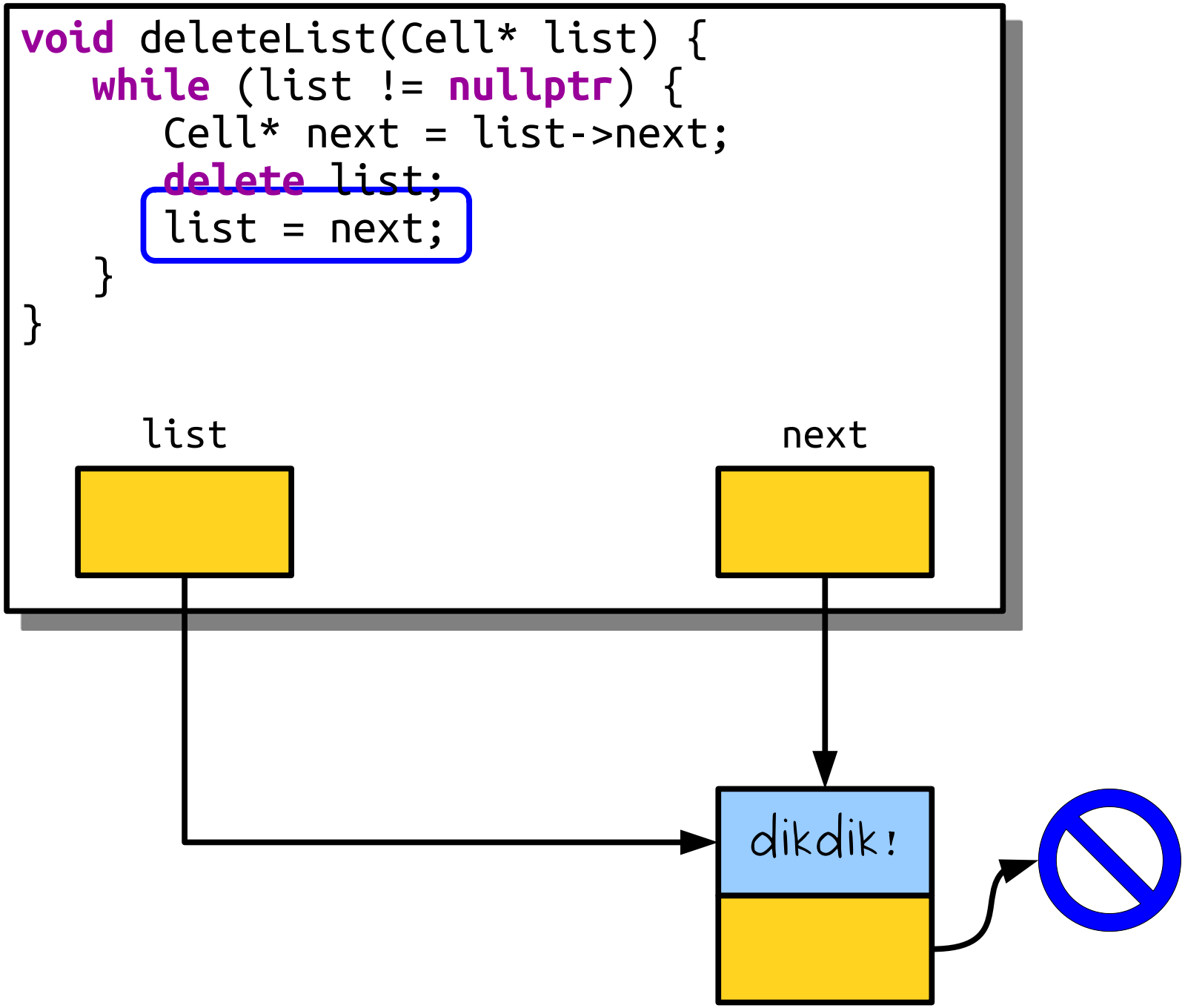
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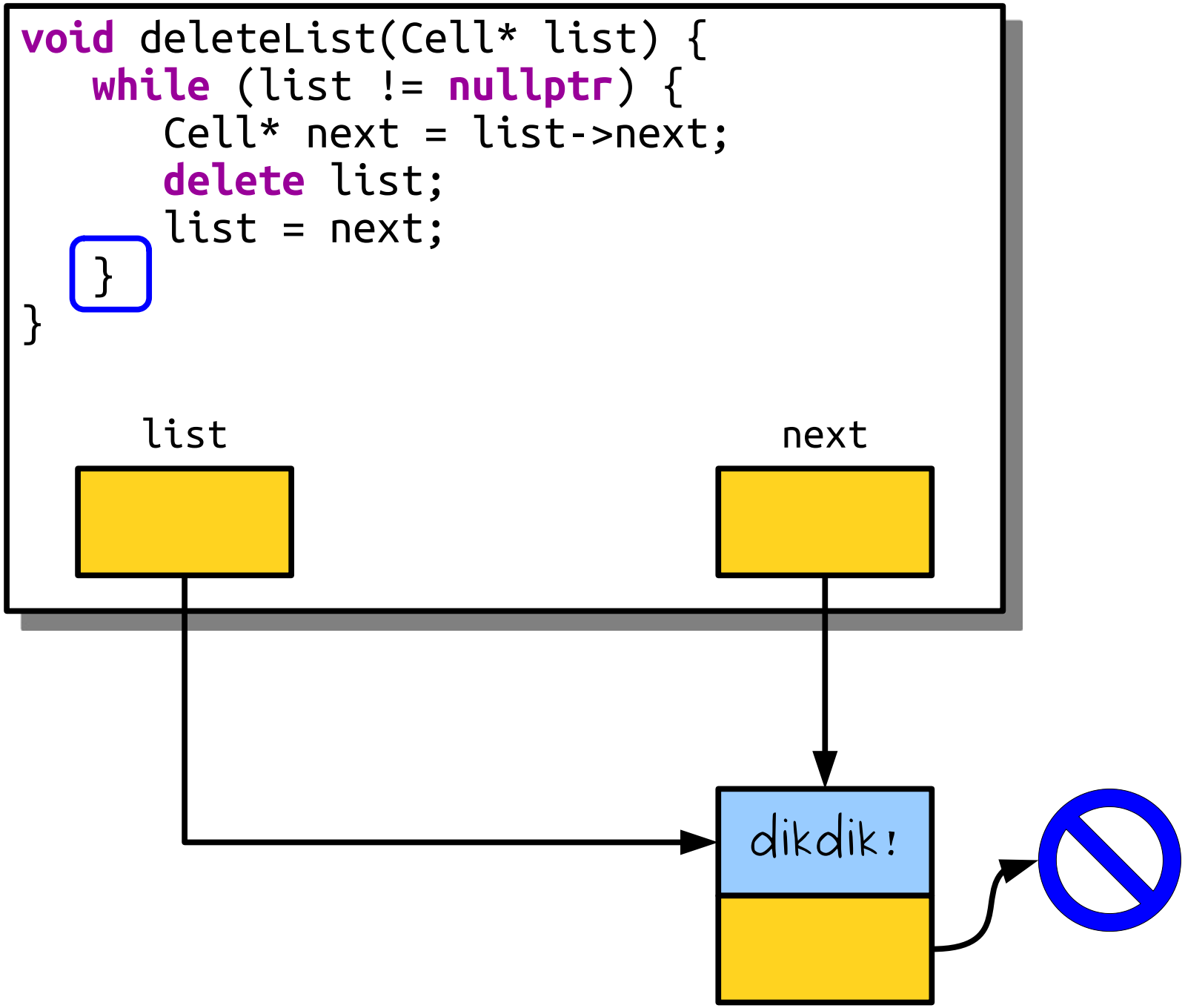
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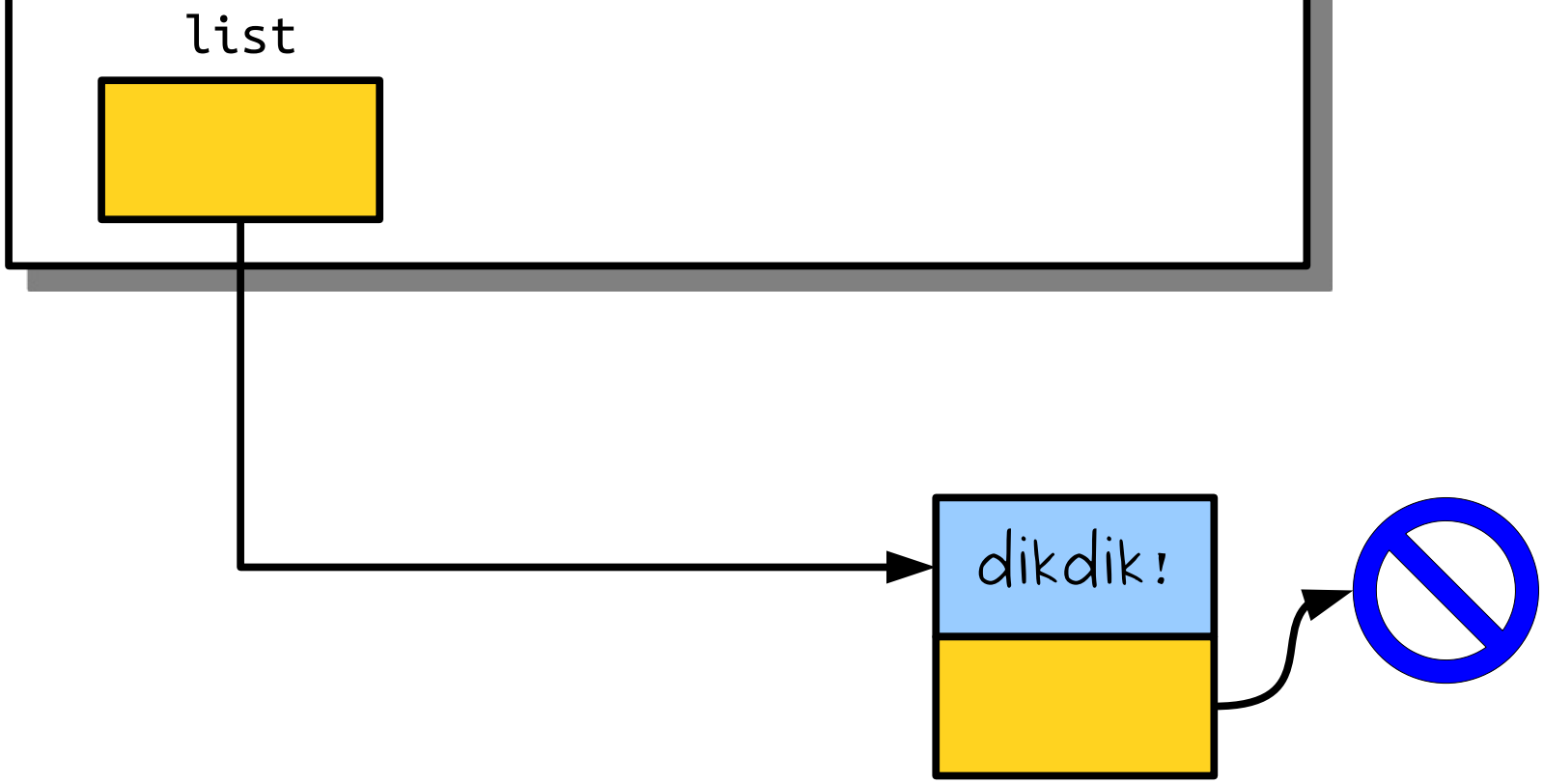

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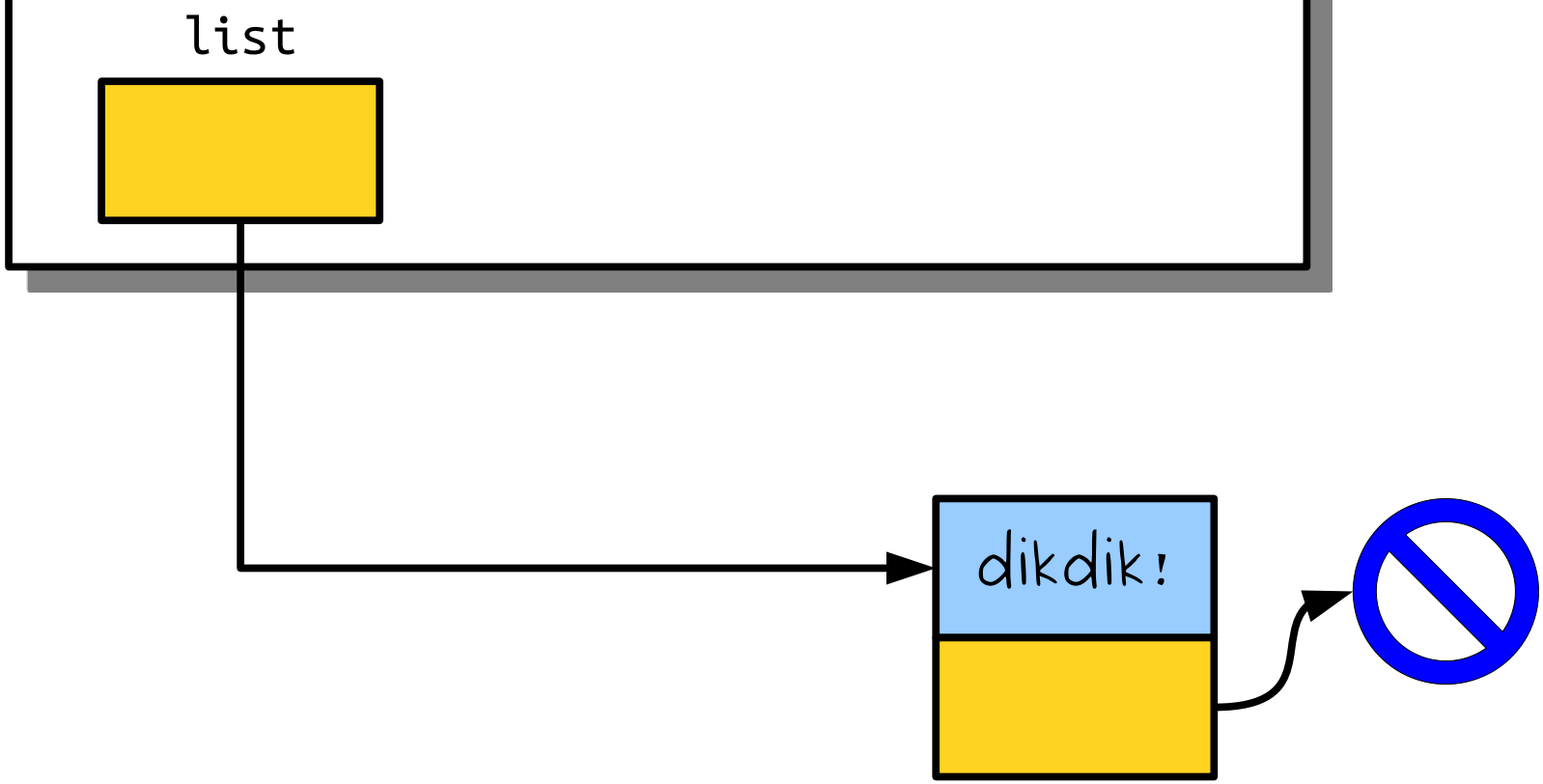

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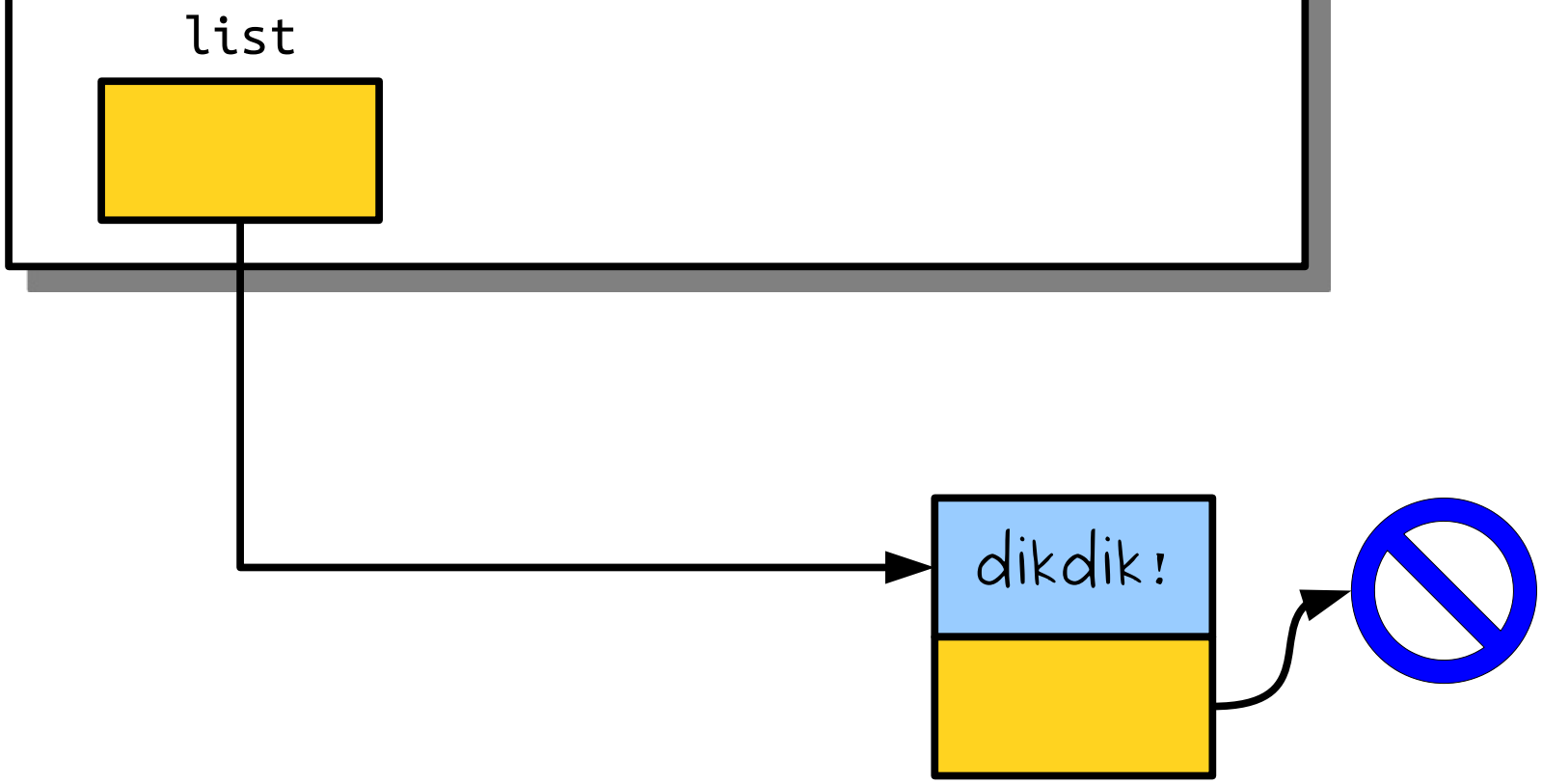

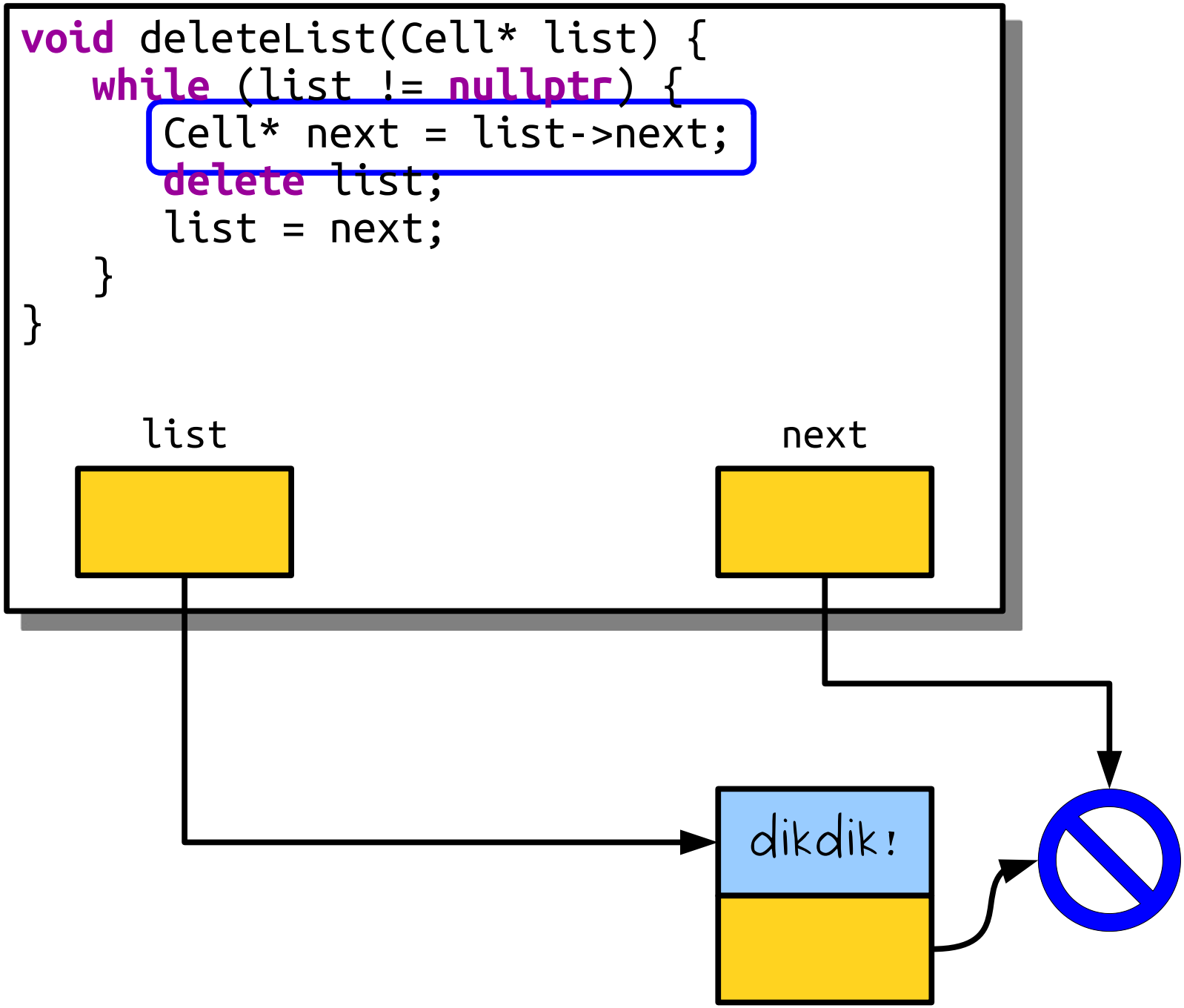
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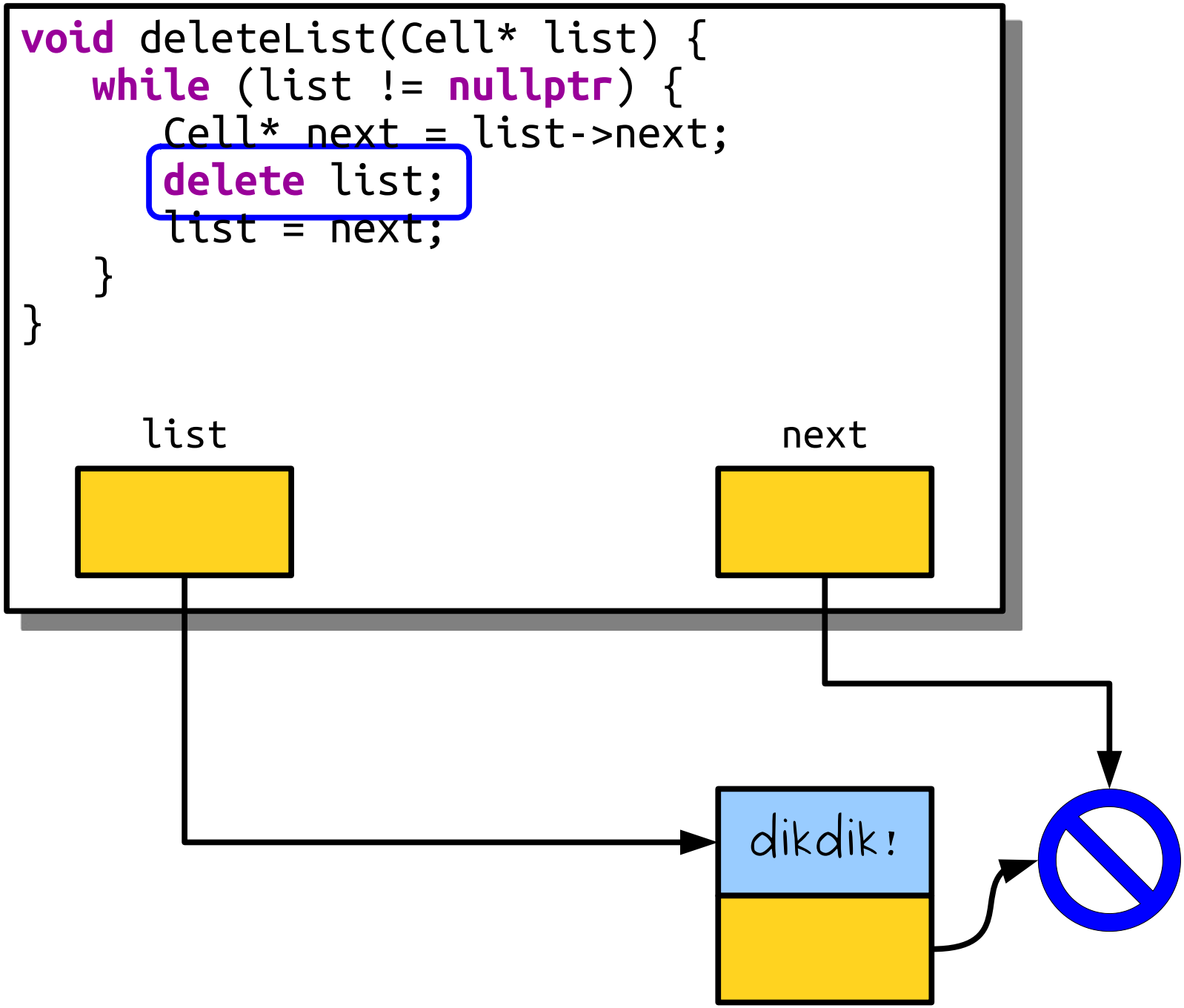
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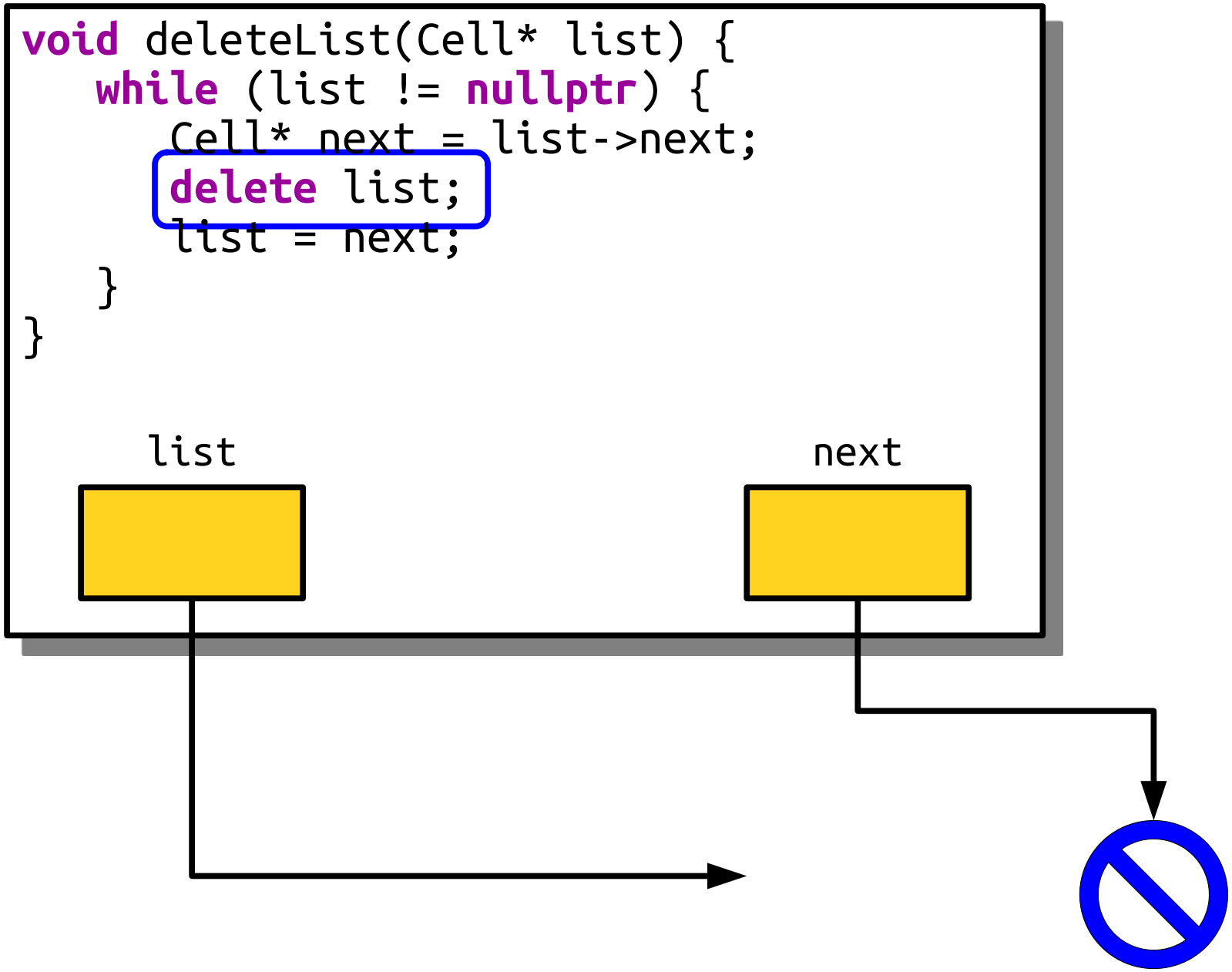
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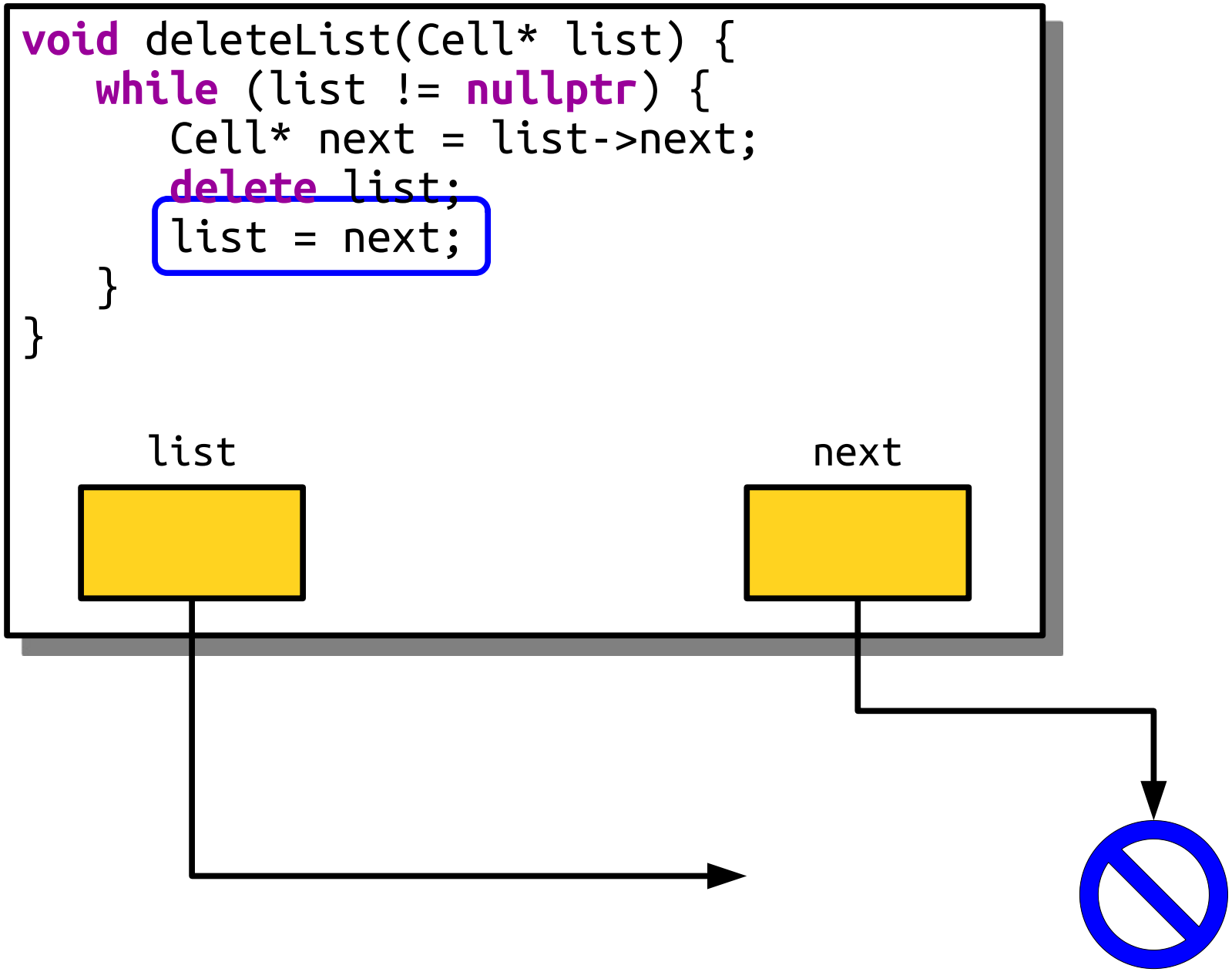
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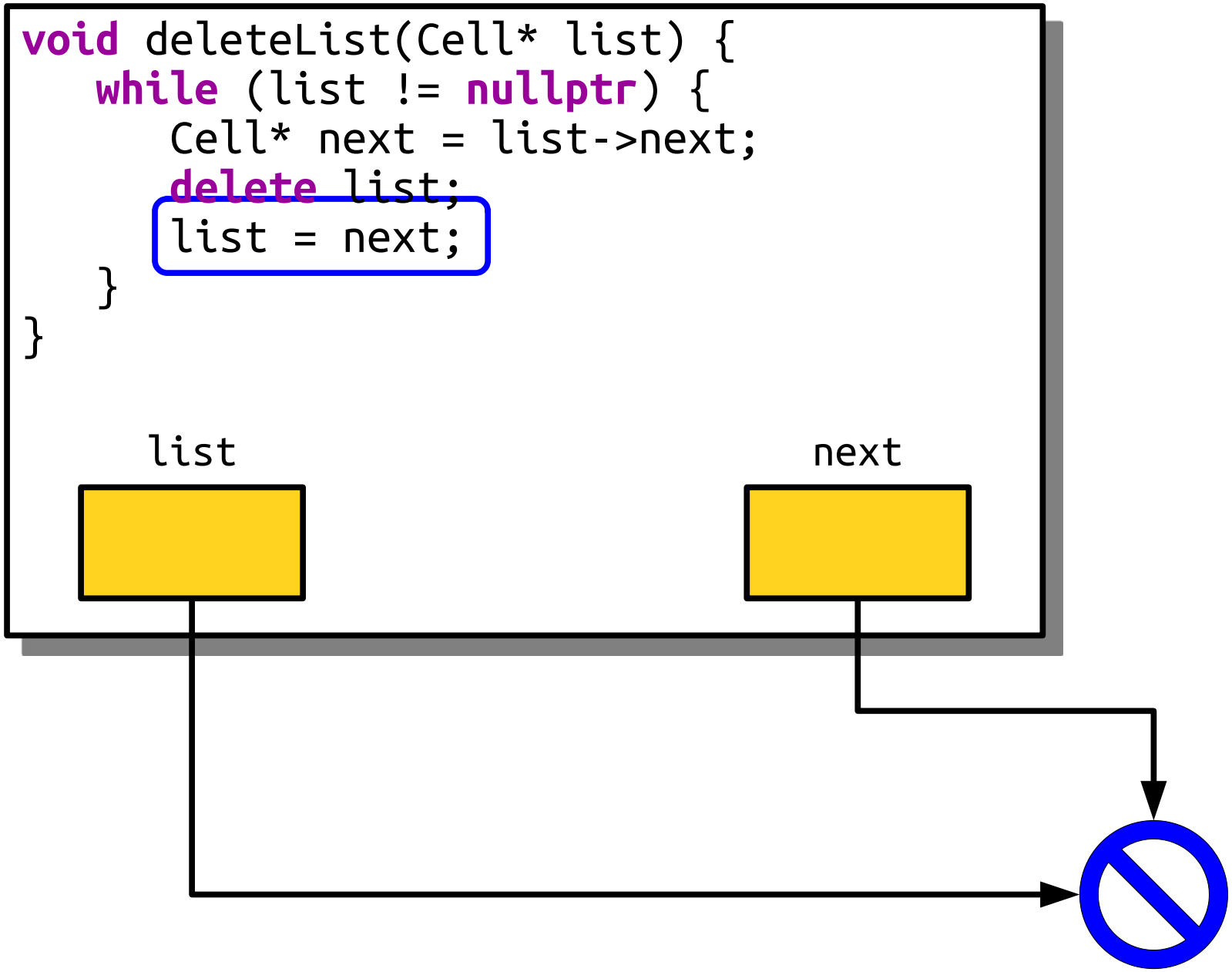
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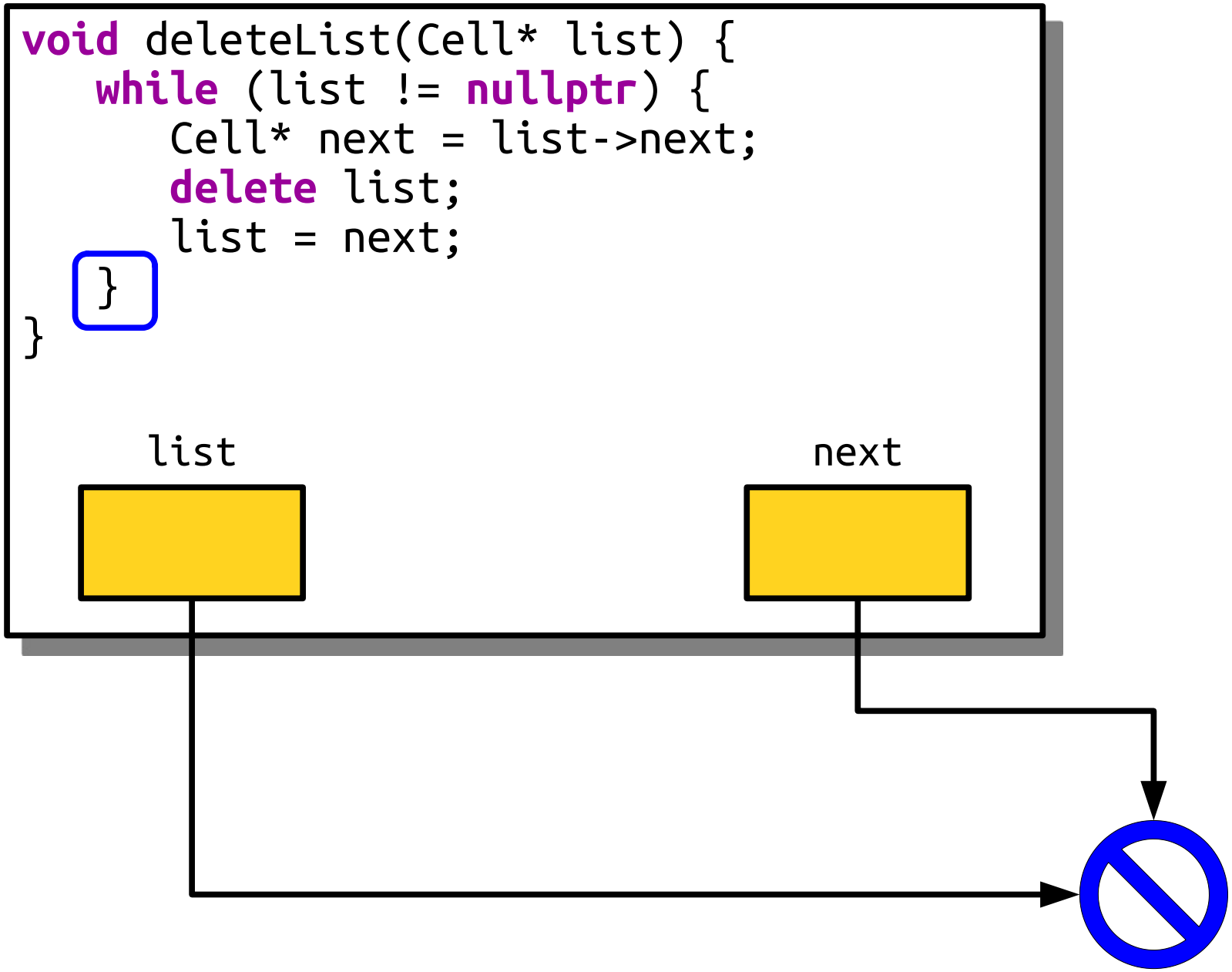
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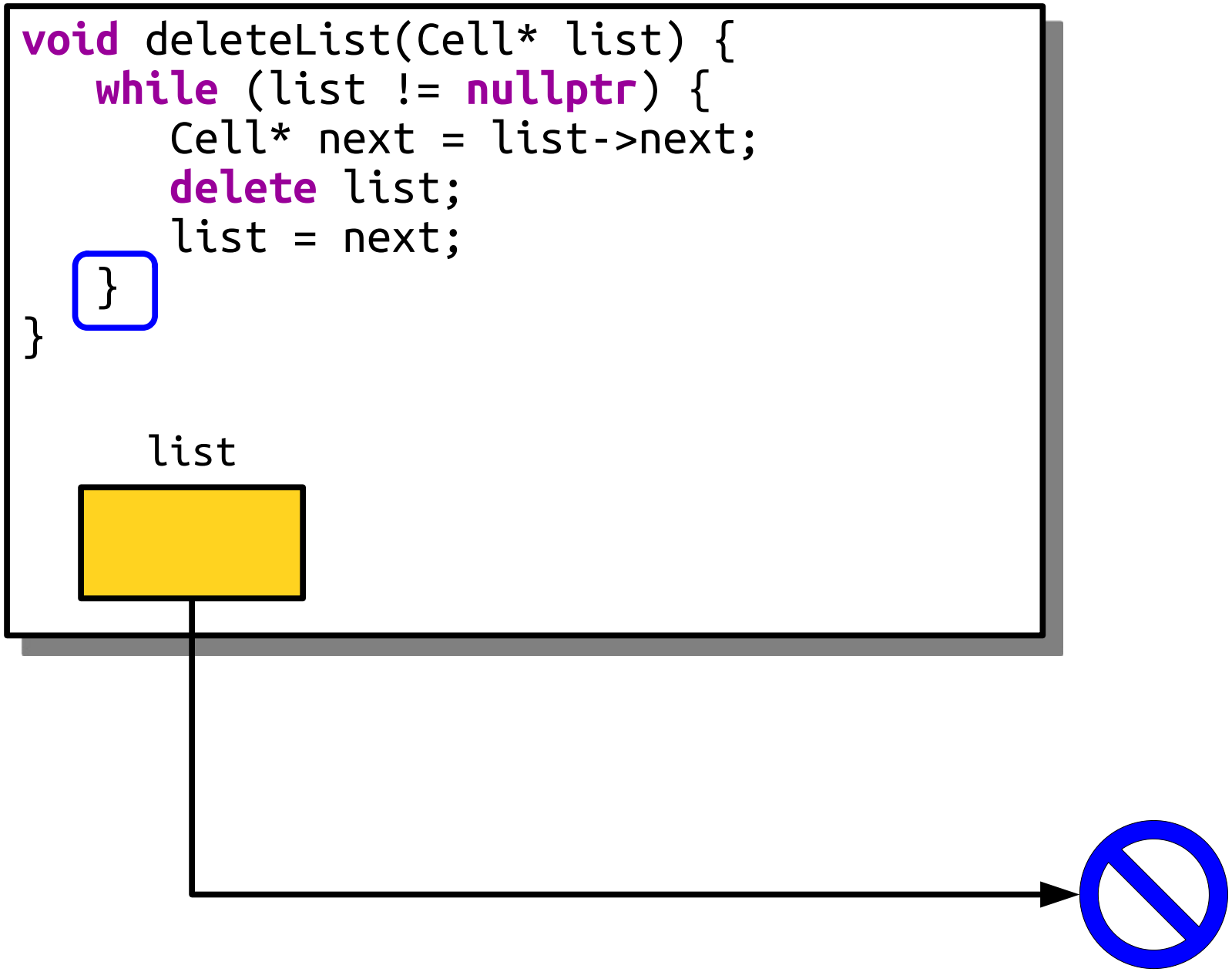
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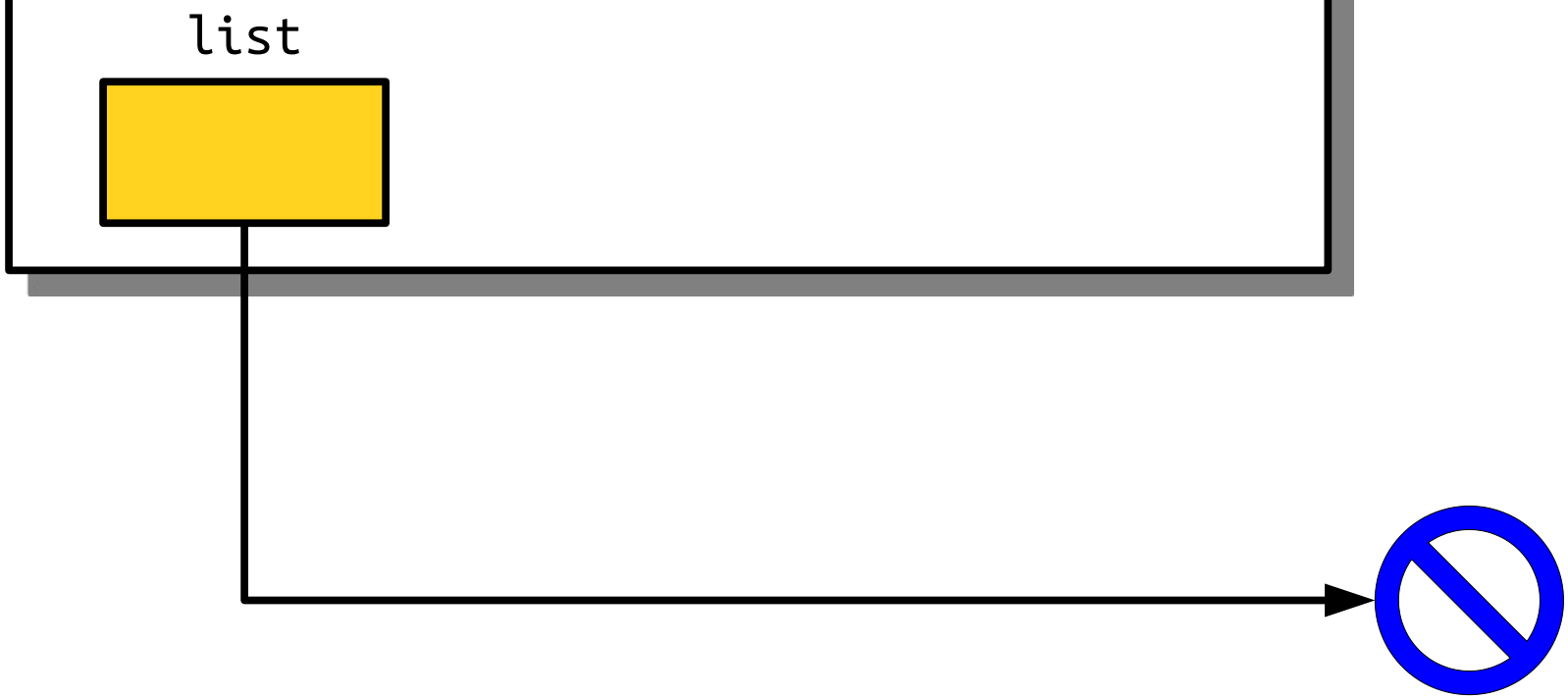

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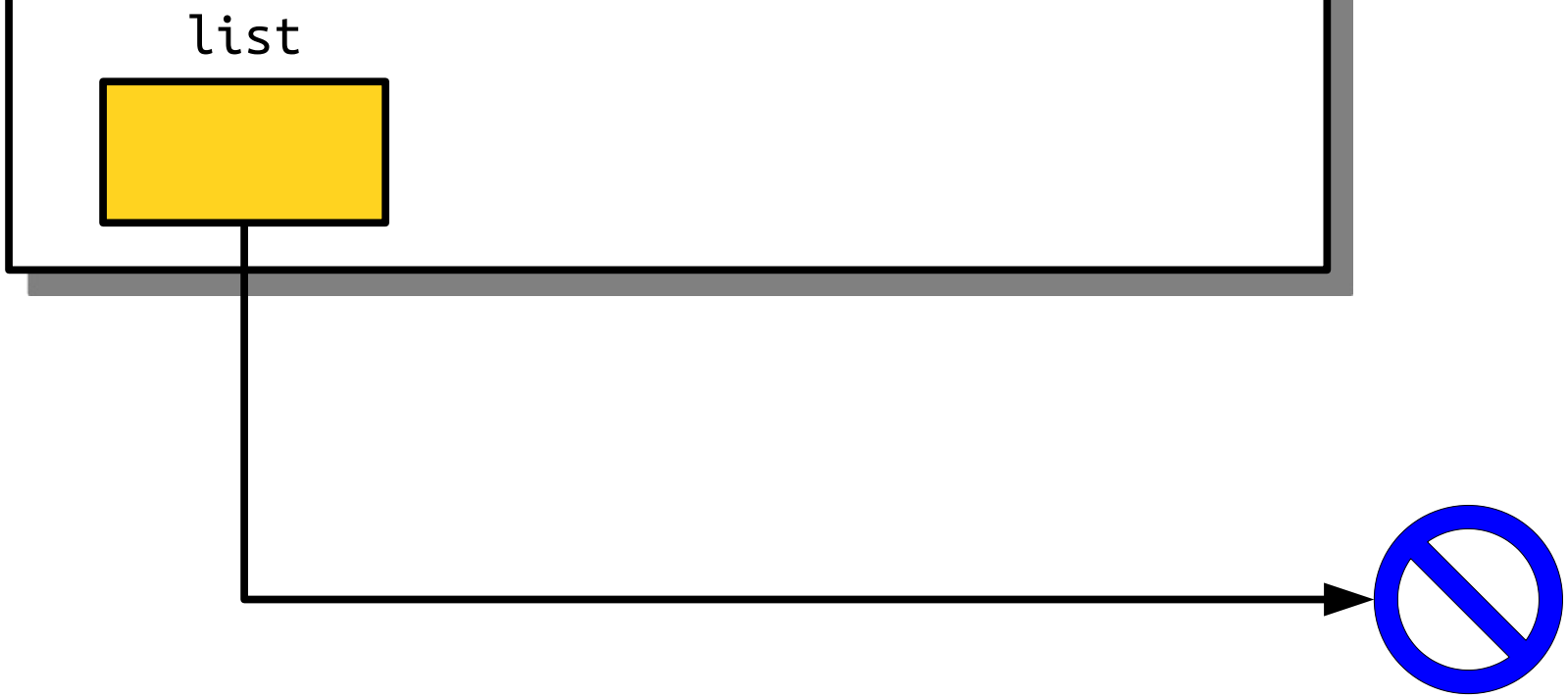
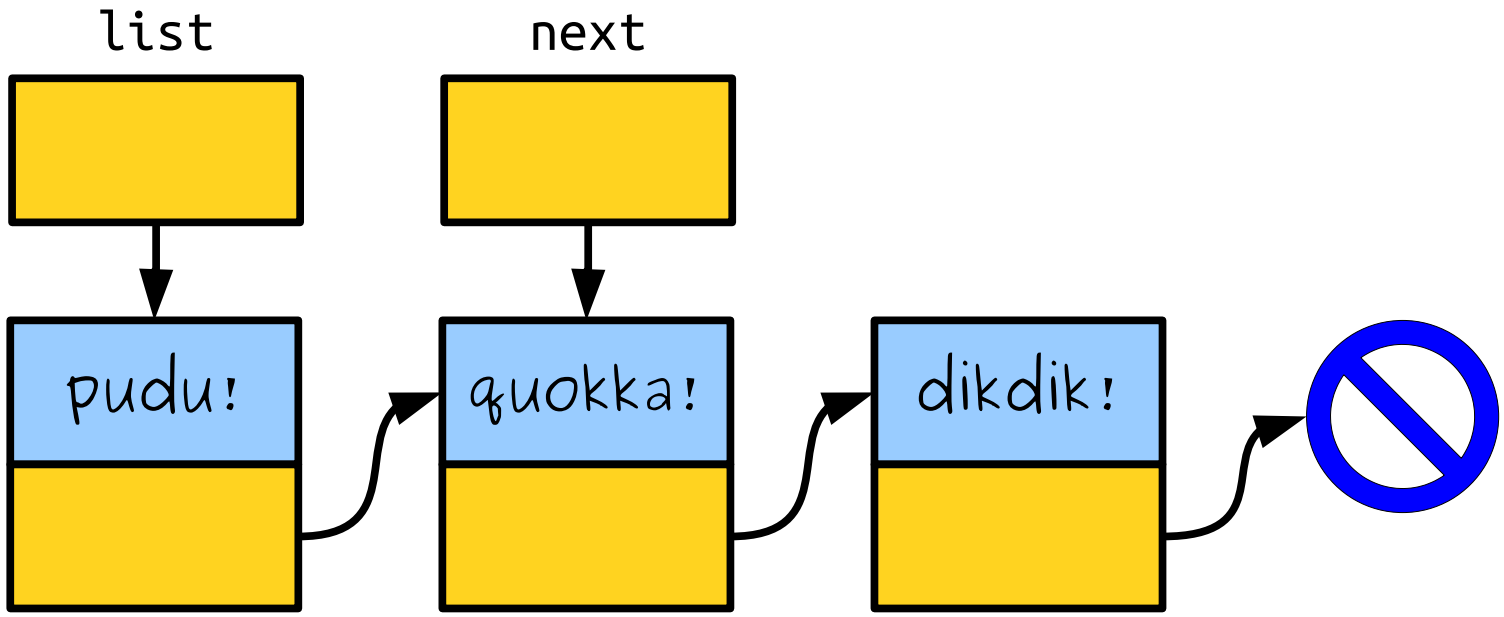


Pointers Into Lists

- When processing linked lists iteratively, it's common to introduce pointers that point to cells in multiple spots in the list.
- This is particularly useful if we're destroying or rewiring existing lists.



Your Action Items

- ***Read Chapter 12.1 – 12.3.***
  - There's lots of useful information in there about how to work with linked lists.
- ***Finish Assignment 7***
  - As always, come talk to us if you have any questions!

Next Time

- ***Pointers by Reference***
  - Getting a helping hand.
- ***Tail Pointers***
  - Harnessing multiple pointers into a list.