Linked Lists

Part One

Outline for Today

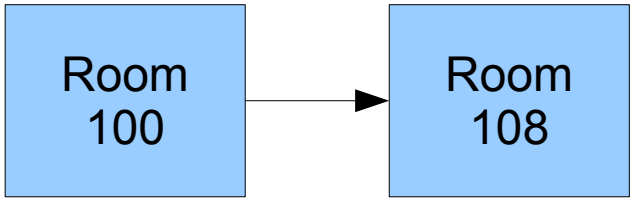
- ***Linked Lists, Conceptually***
  - A different way to represent a sequence.
- ***Linked Lists, In Code***
  - Some cool new C++ tricks.

Changing Offices

The Sign on Room 100

Dr. Cynthia Lee is no longer in room 100.

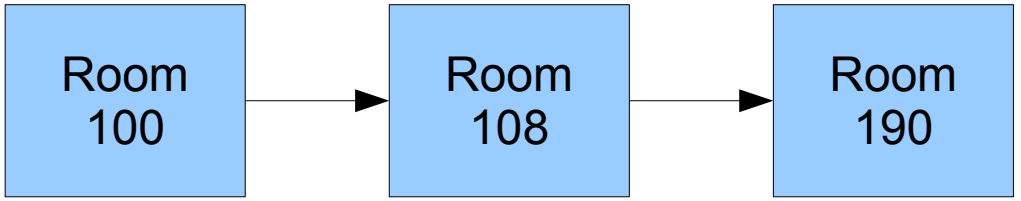
She can be found in room 108.



The Sign on Room 108

Dr. Cynthia Lee is no longer in room 108.

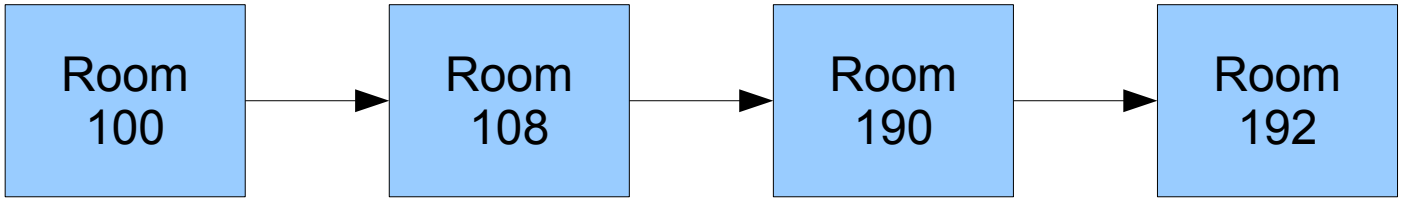
She can be found in room 190.



The Sign on Room 190

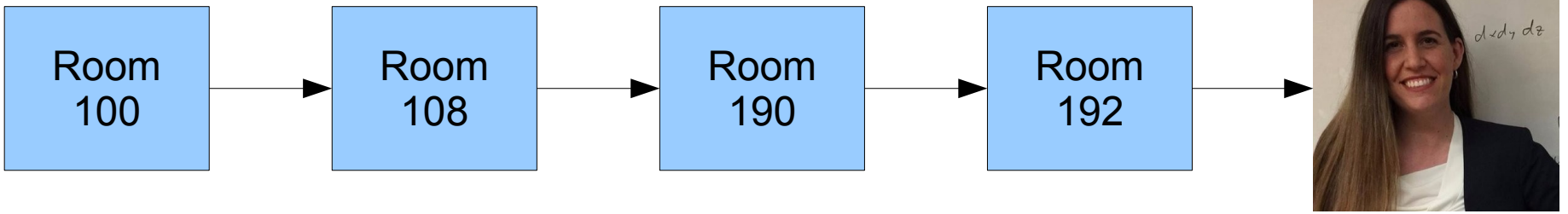
Dr. Cynthia Lee is no longer in room 190.

She can be found in room 192.



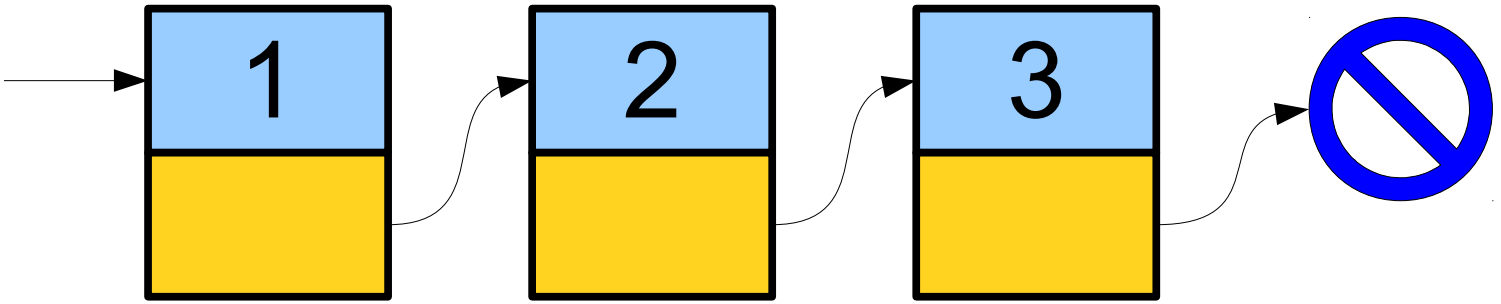
The Sign on Room 192

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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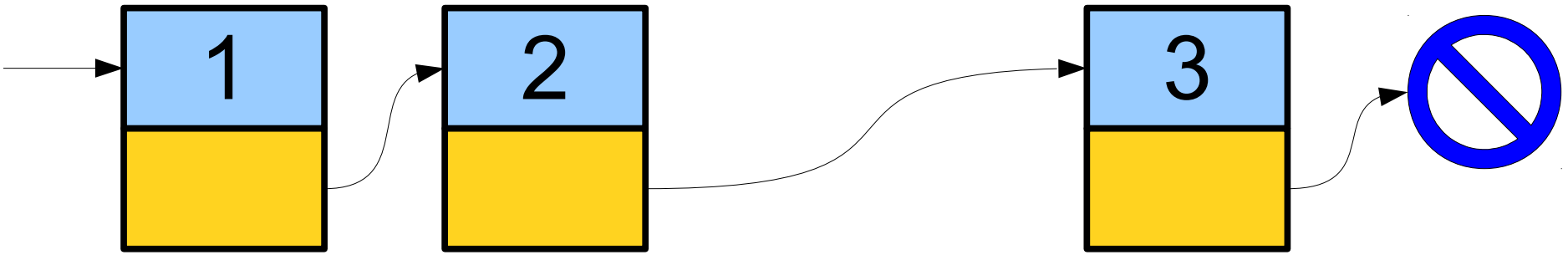

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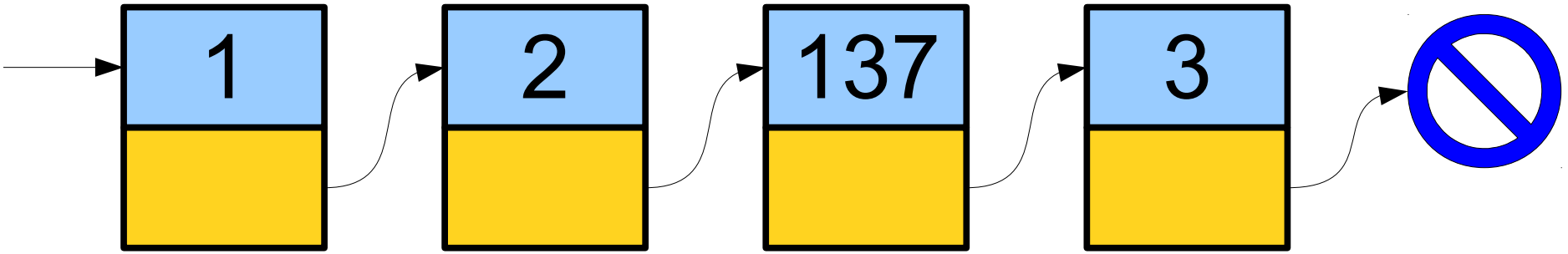

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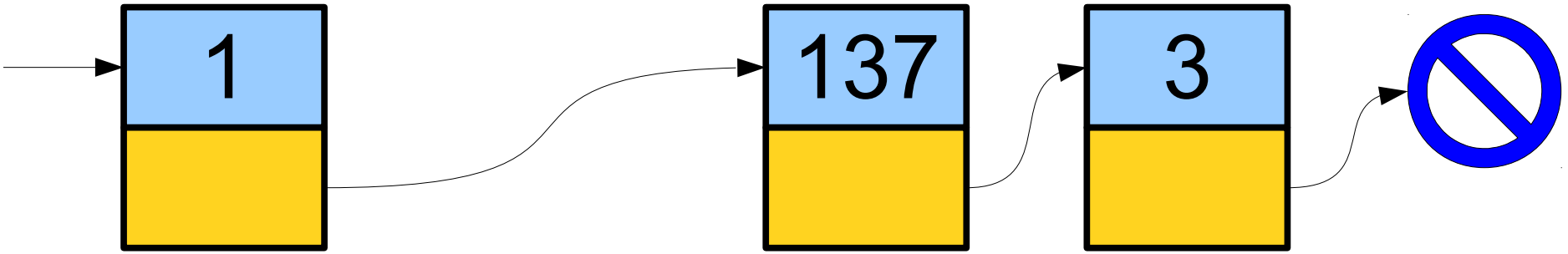
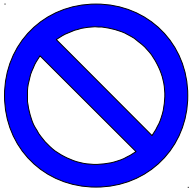
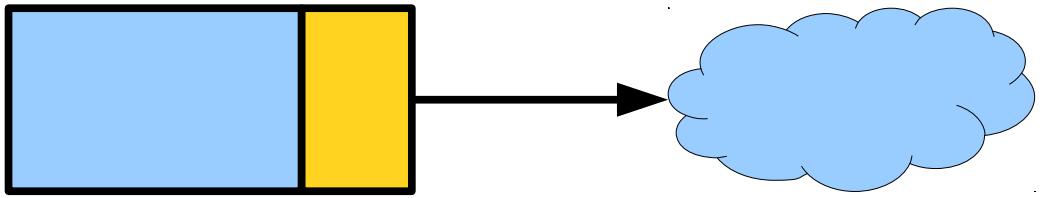


A Linked List is Either…

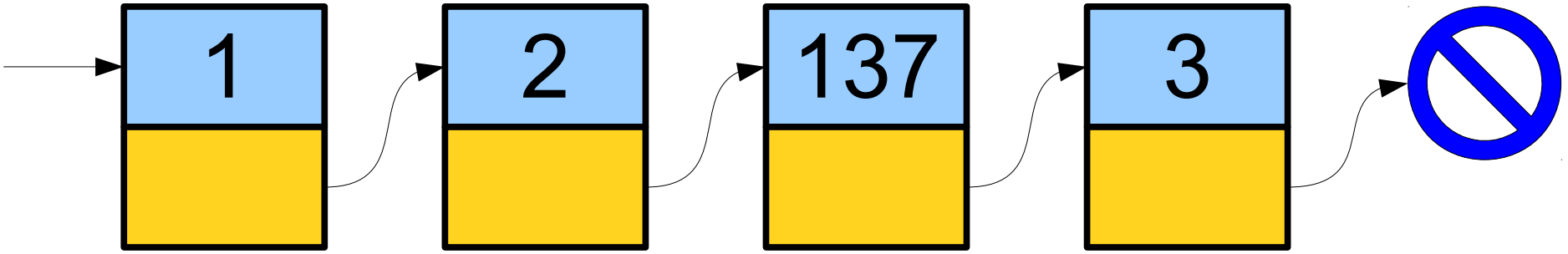
…an empty list,
or…





a single cell…

… that points at another linked list.



Representing Linked Lists

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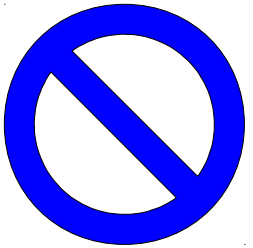

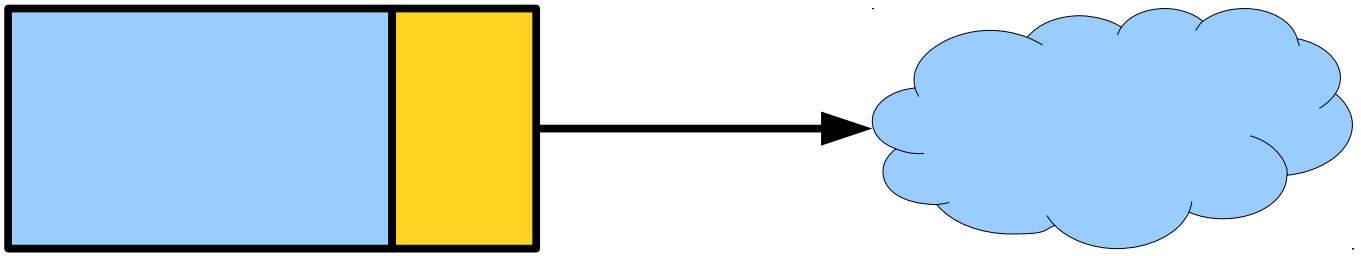

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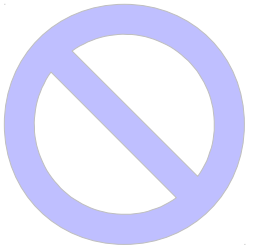

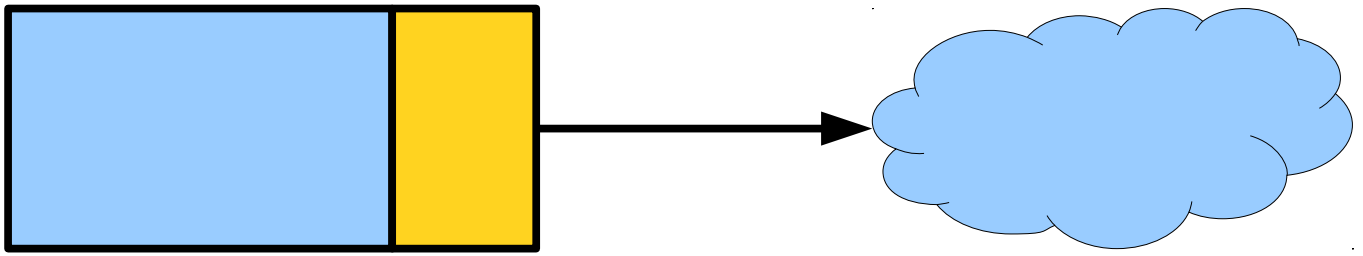

a single cell…

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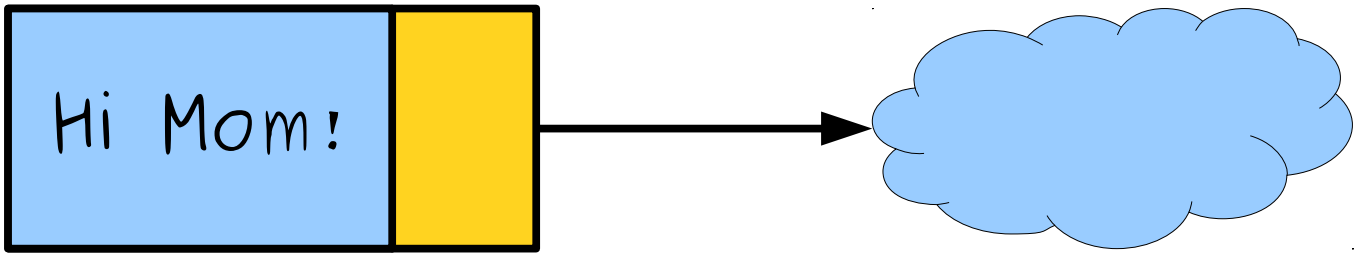
```
struct Cell {
    string value;
    Cell* next;
};
```



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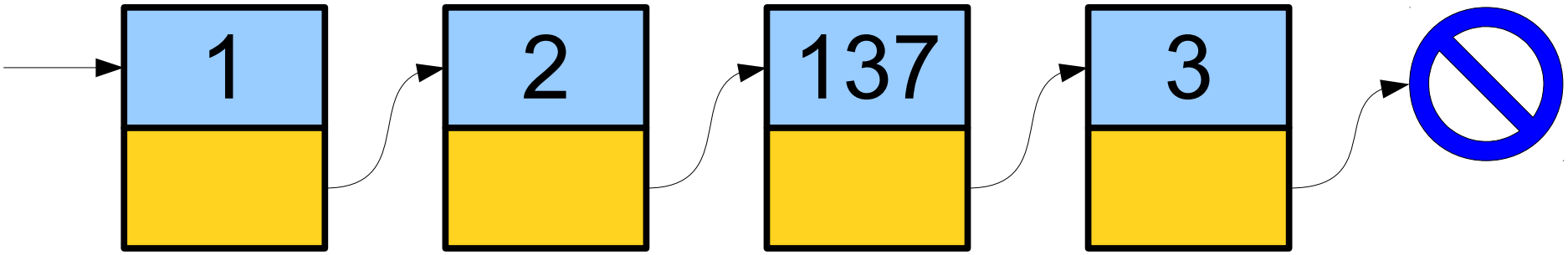
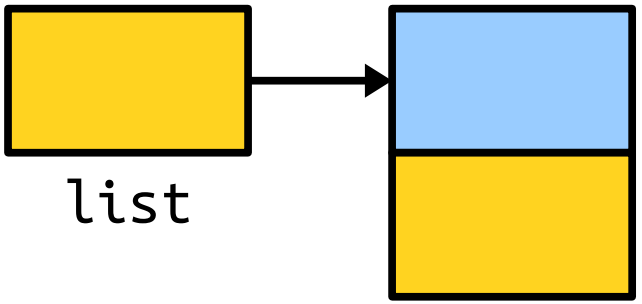


```
struct Cell {
    string value;
    Cell* next;
};

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`!"



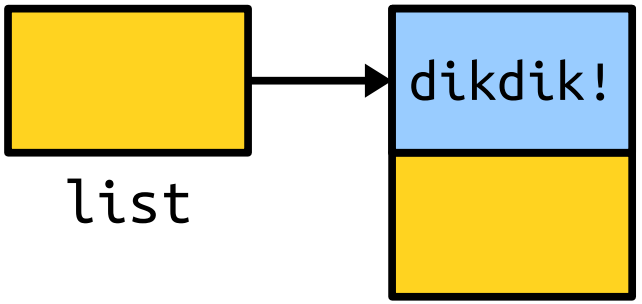
Yes, it's a bit confusing that C++ uses the same types to mean "look over there for an array of `Cells`" and "look over there for a single `Cell`."

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

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

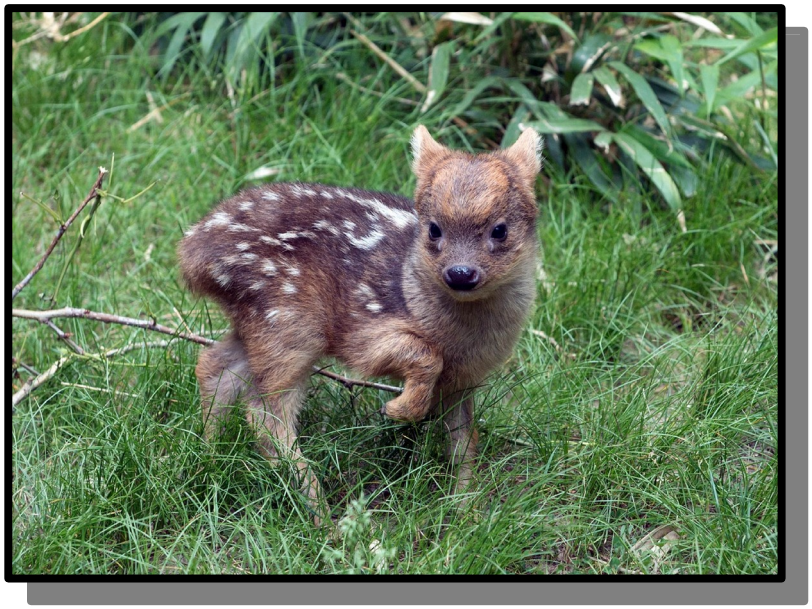
Because list is a pointer to a `Cell`, we use the arrow operator `->` instead of the dot operator.

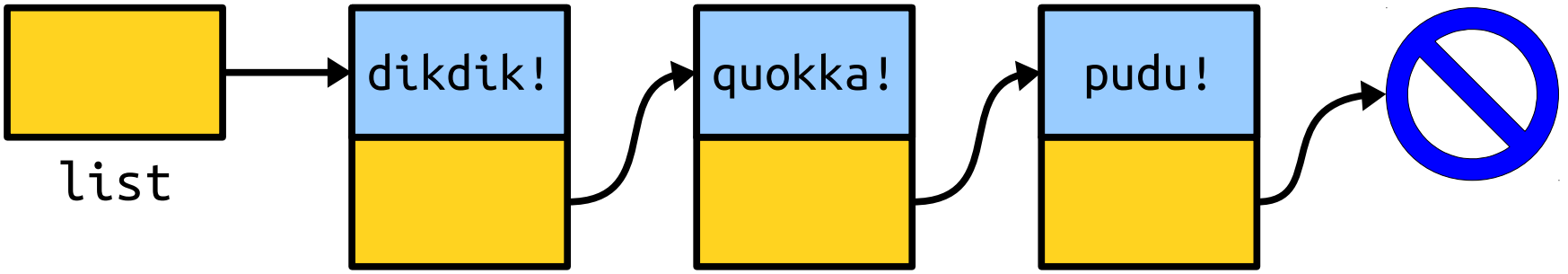
Think of `list->value` as saying “start at `list`, follow an arrow, then pick the `value` field.”



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

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





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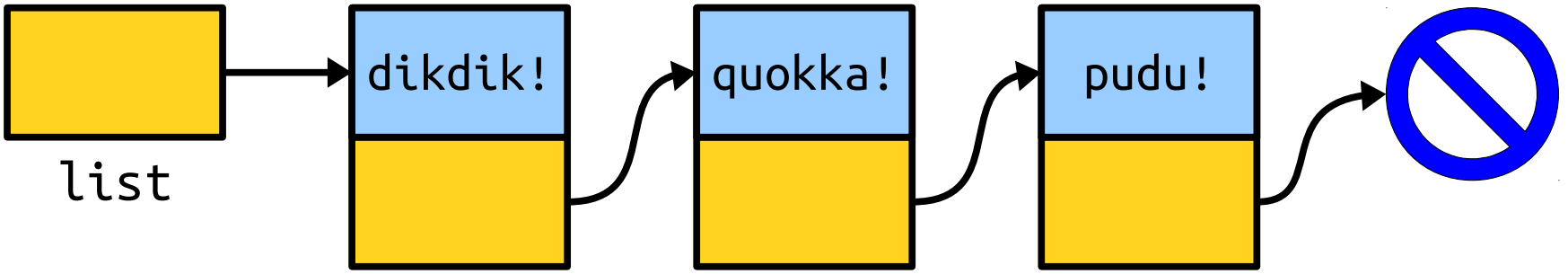
list->next->next = new Cell;
list->next->next->value = "pudu!";
list->next->next->next = nullptr;
```

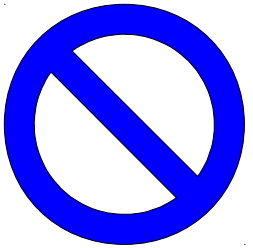
C++ uses the **nullptr** keyword to mean “a pointer that doesn’t point at anything.”

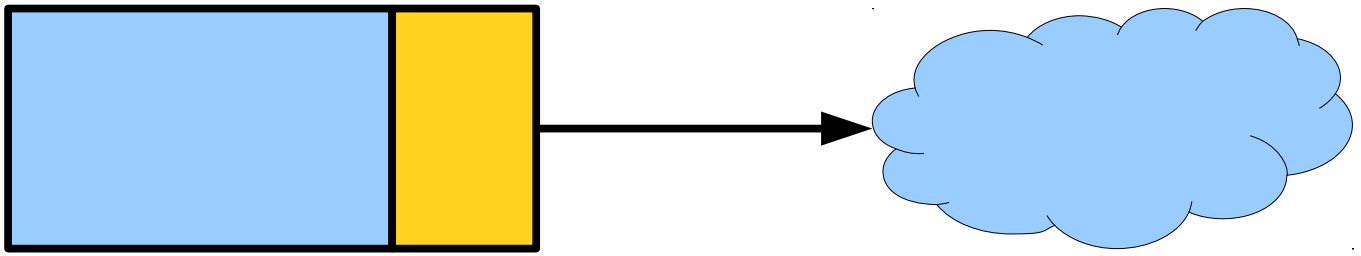
(Older code uses NULL instead of **nullptr**; that’s also okay, but we recommend **nullptr**.)



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

A Linked List is Either…

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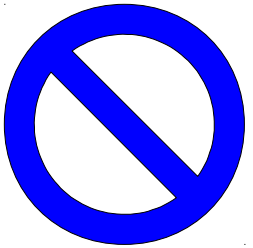

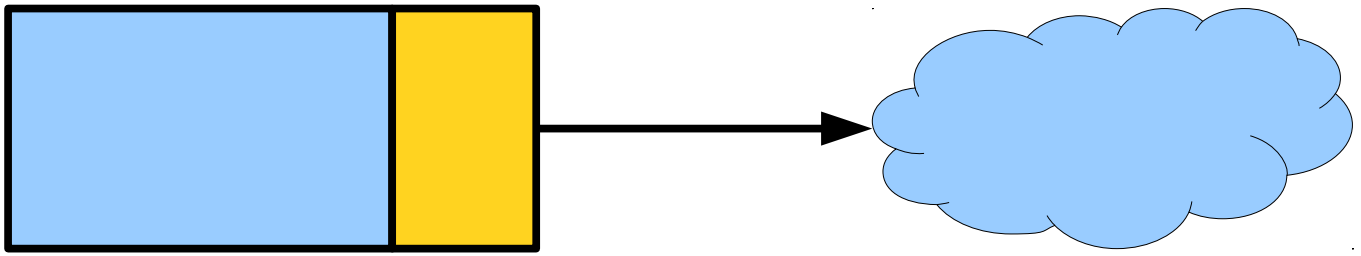

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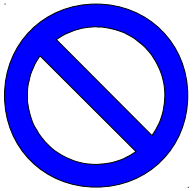

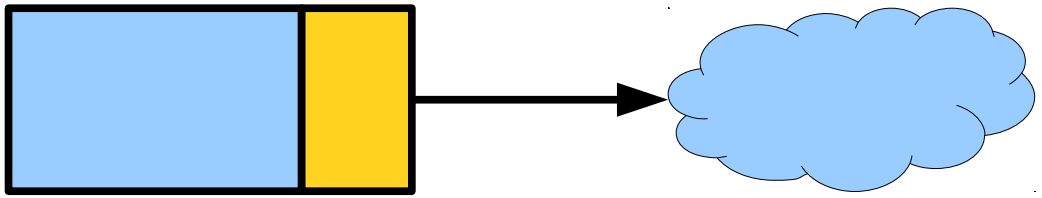

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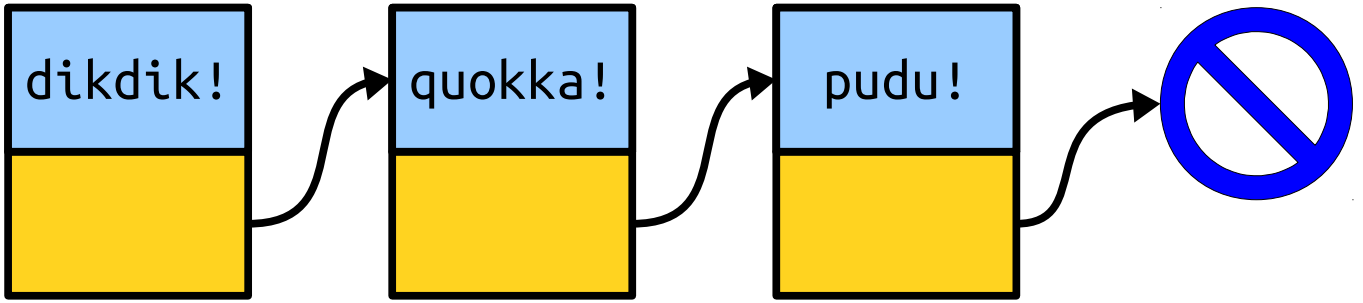

Printing a Linked List

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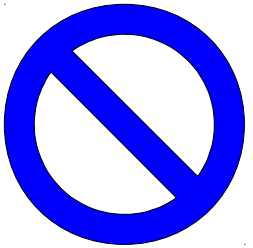

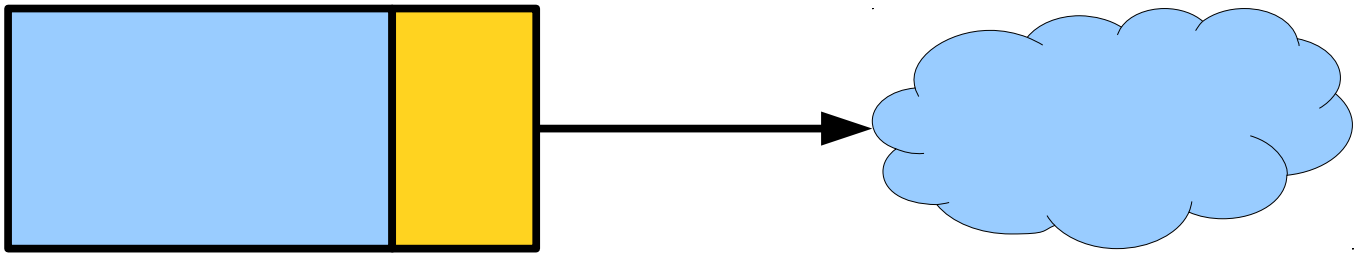

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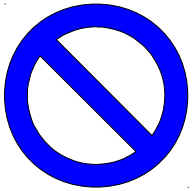

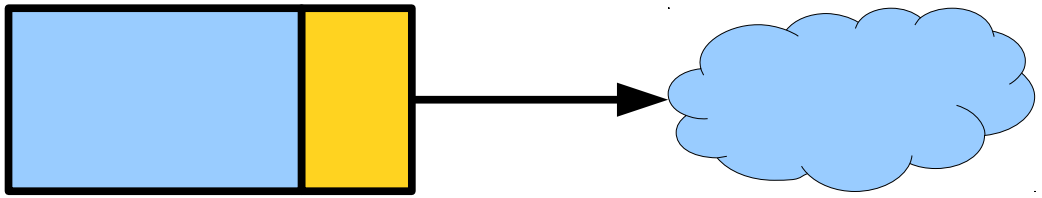

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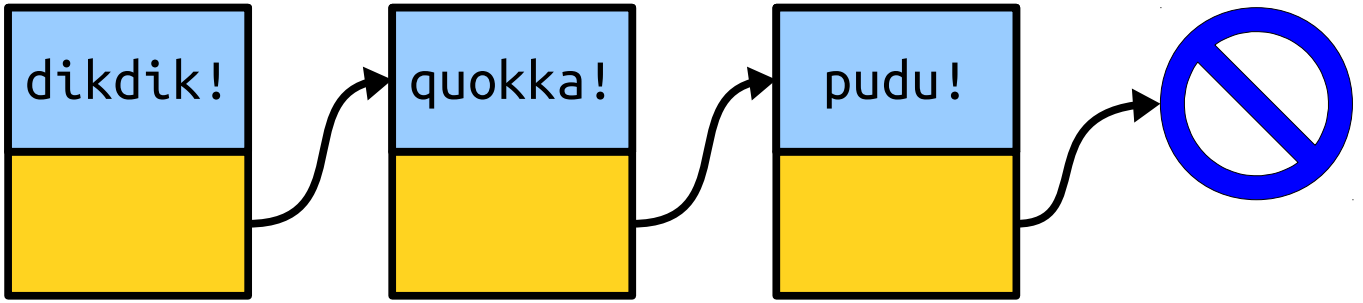

Building a Linked List

(without hardcoding it)

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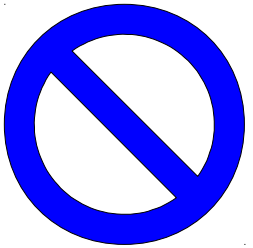

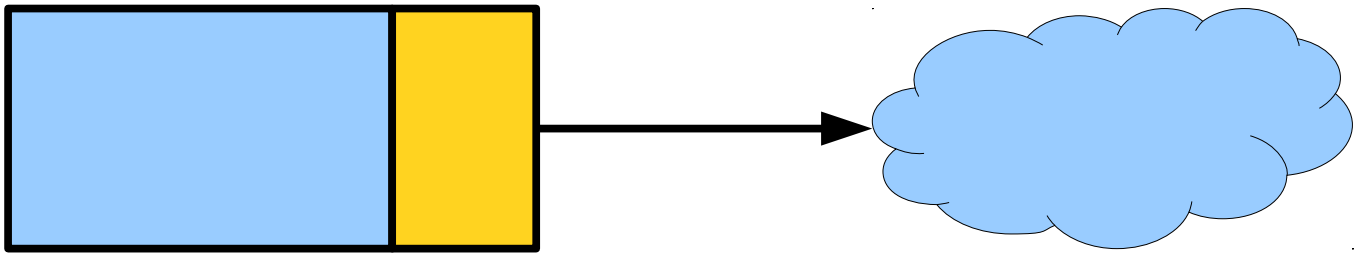

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Cleaning Up a Linked List

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;
```

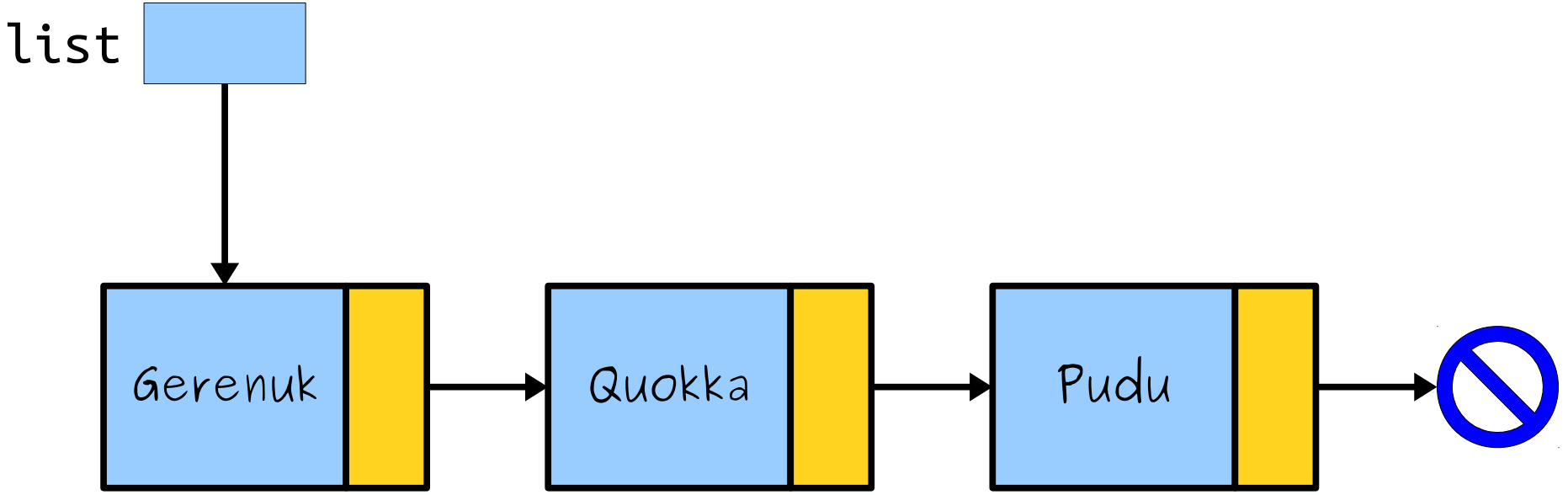
- ***Make sure to use the proper deletion operation***. Mixing these up leads to Undefined Behavior.

Cleaning Up Memory

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

```
delete list;
```

- Why not?



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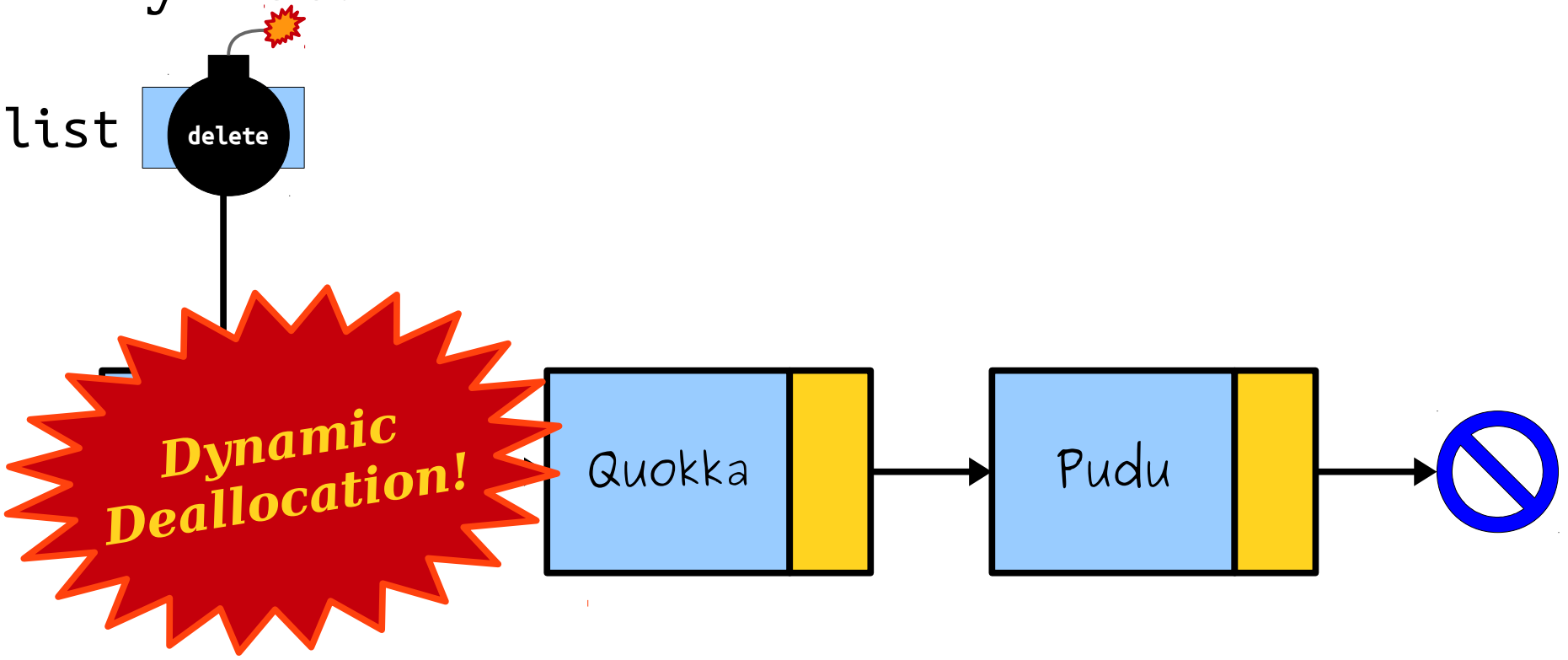

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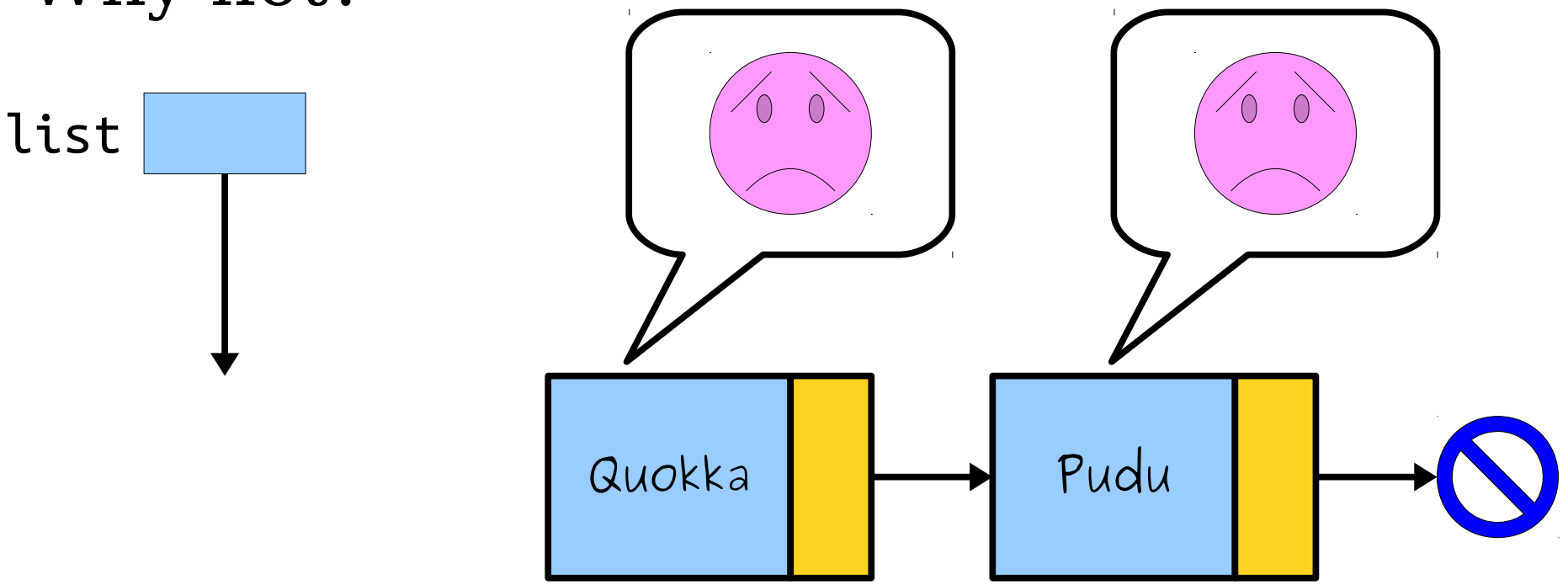

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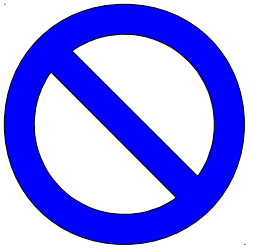

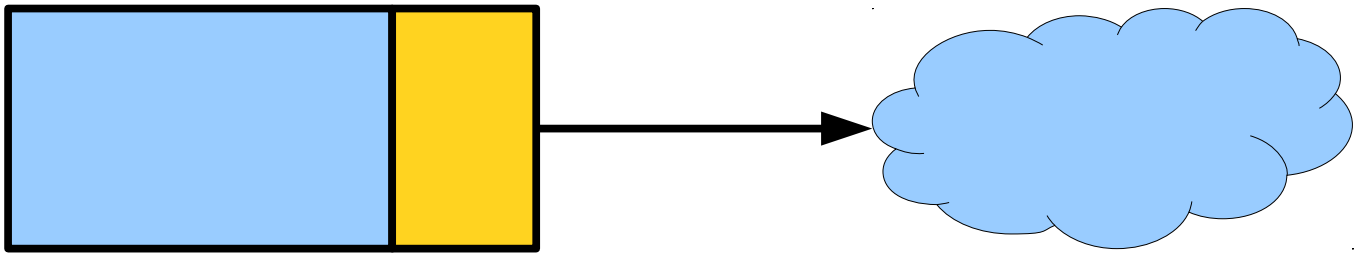

a single linked list cell that points…

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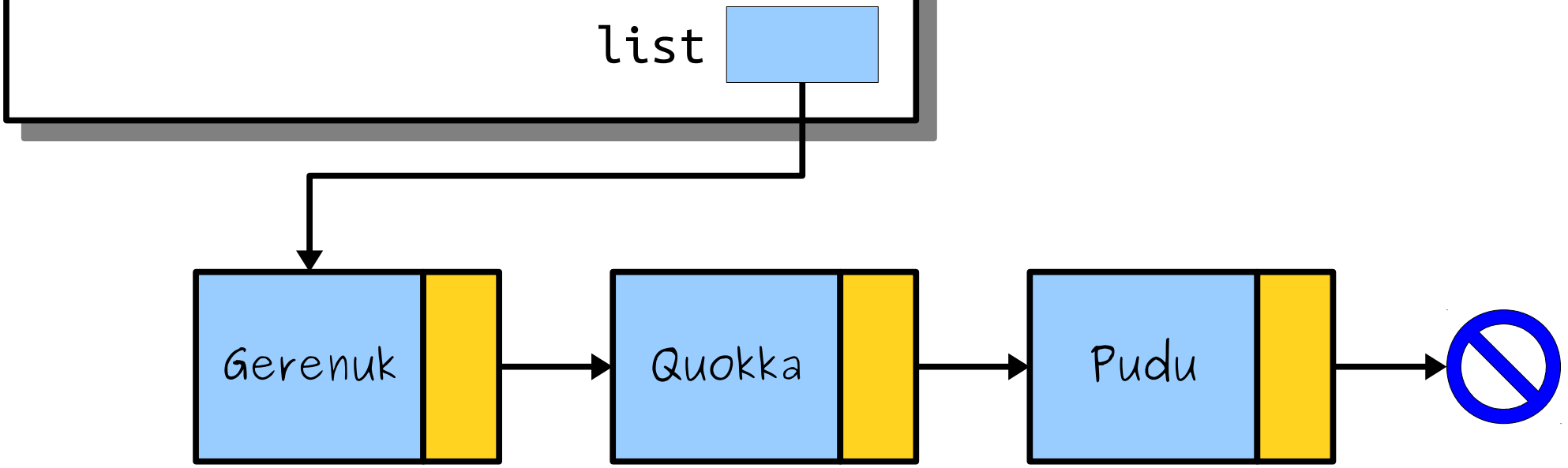
Watch Out!

```
void deleteList(Cell* list) {
    if (list == nullptr) return;

    delete list;
    deleteList(list->next);
}
```



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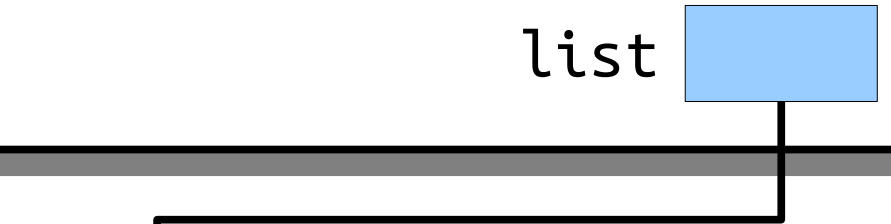

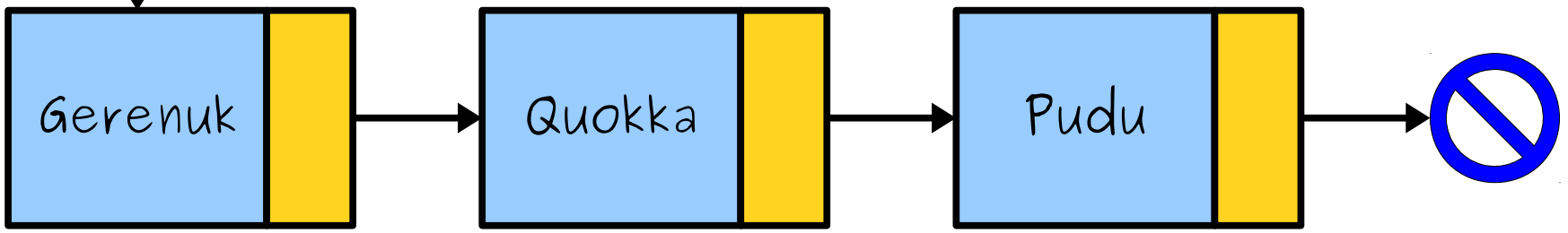

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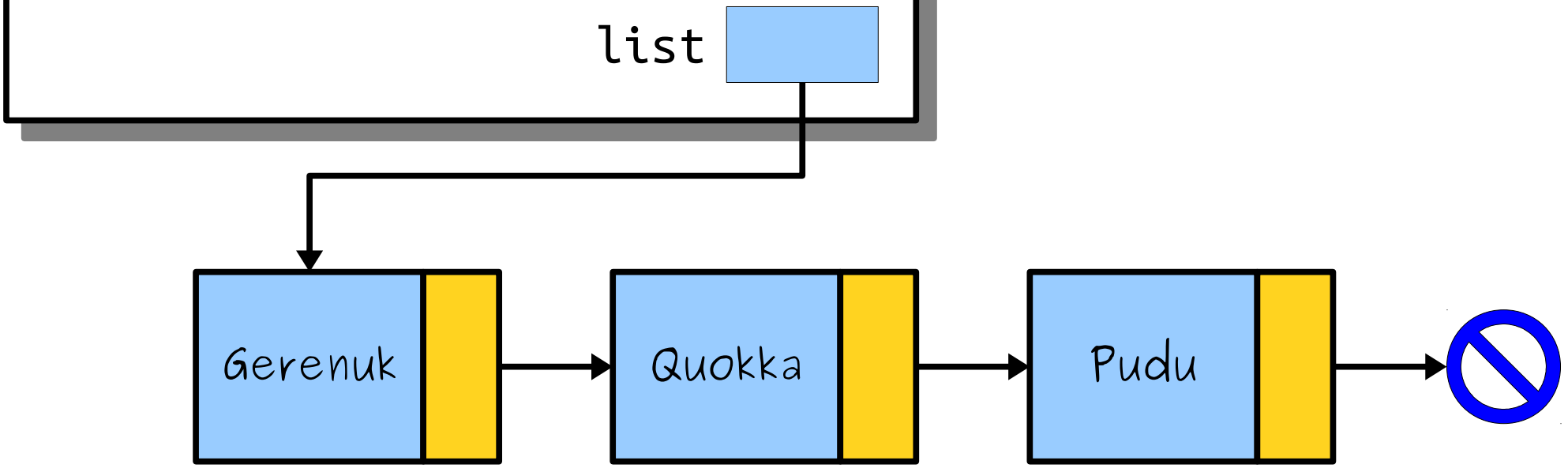

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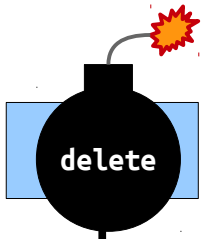

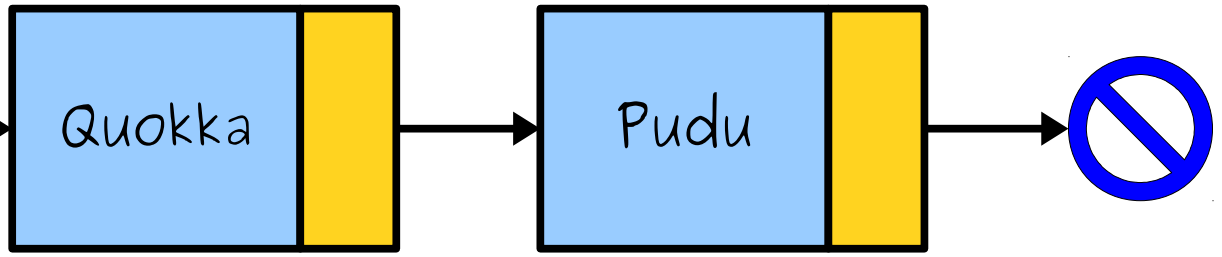

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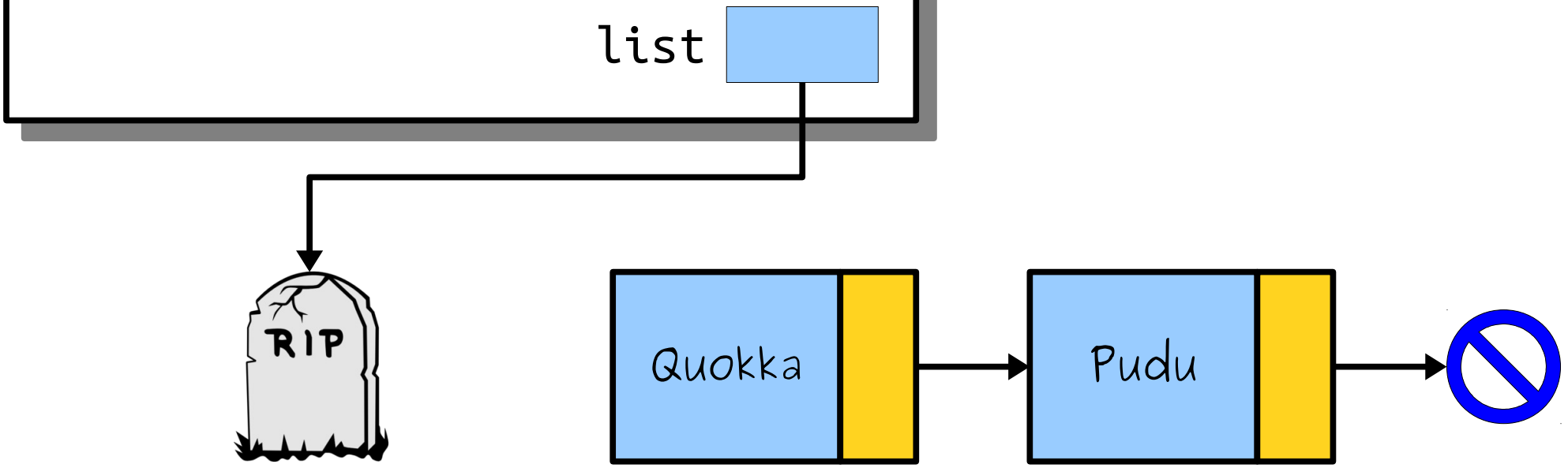
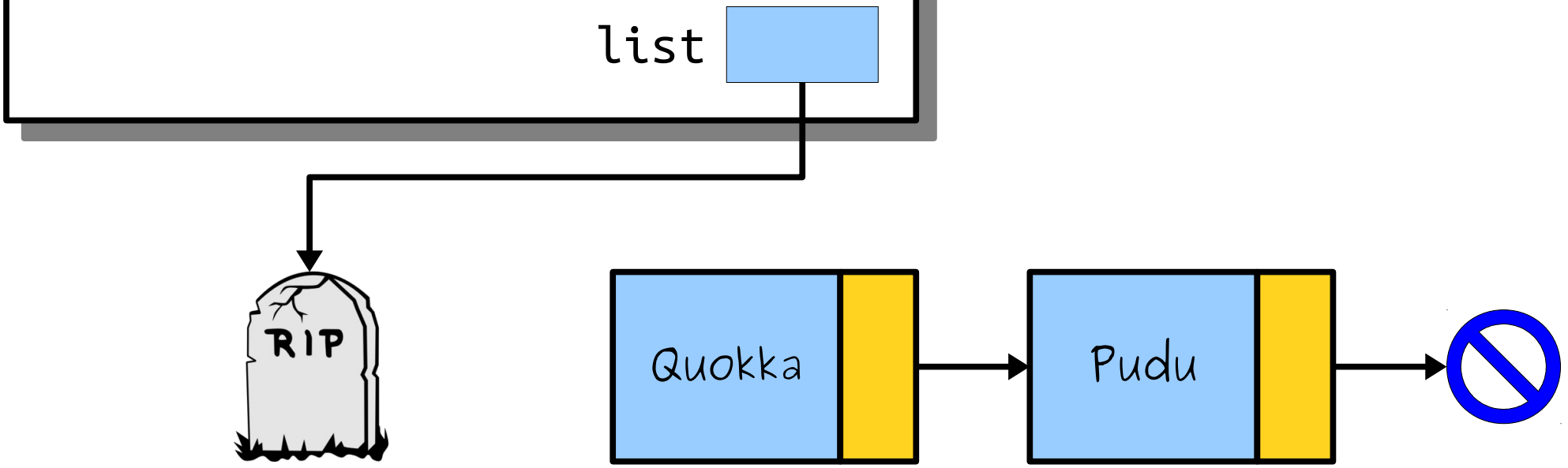


Watch Out!

```
void deleteList(Cell* list) {
    if (list == nullptr) return;

    delete list;
    deleteList(list->next);
}
```



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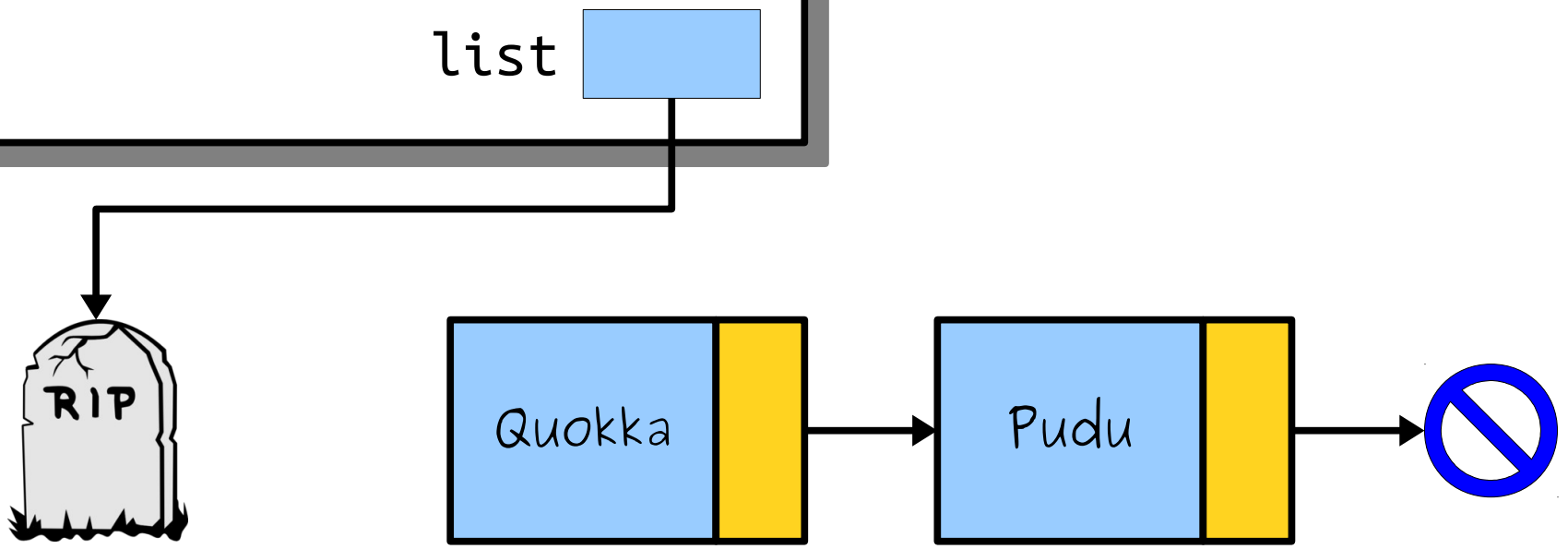
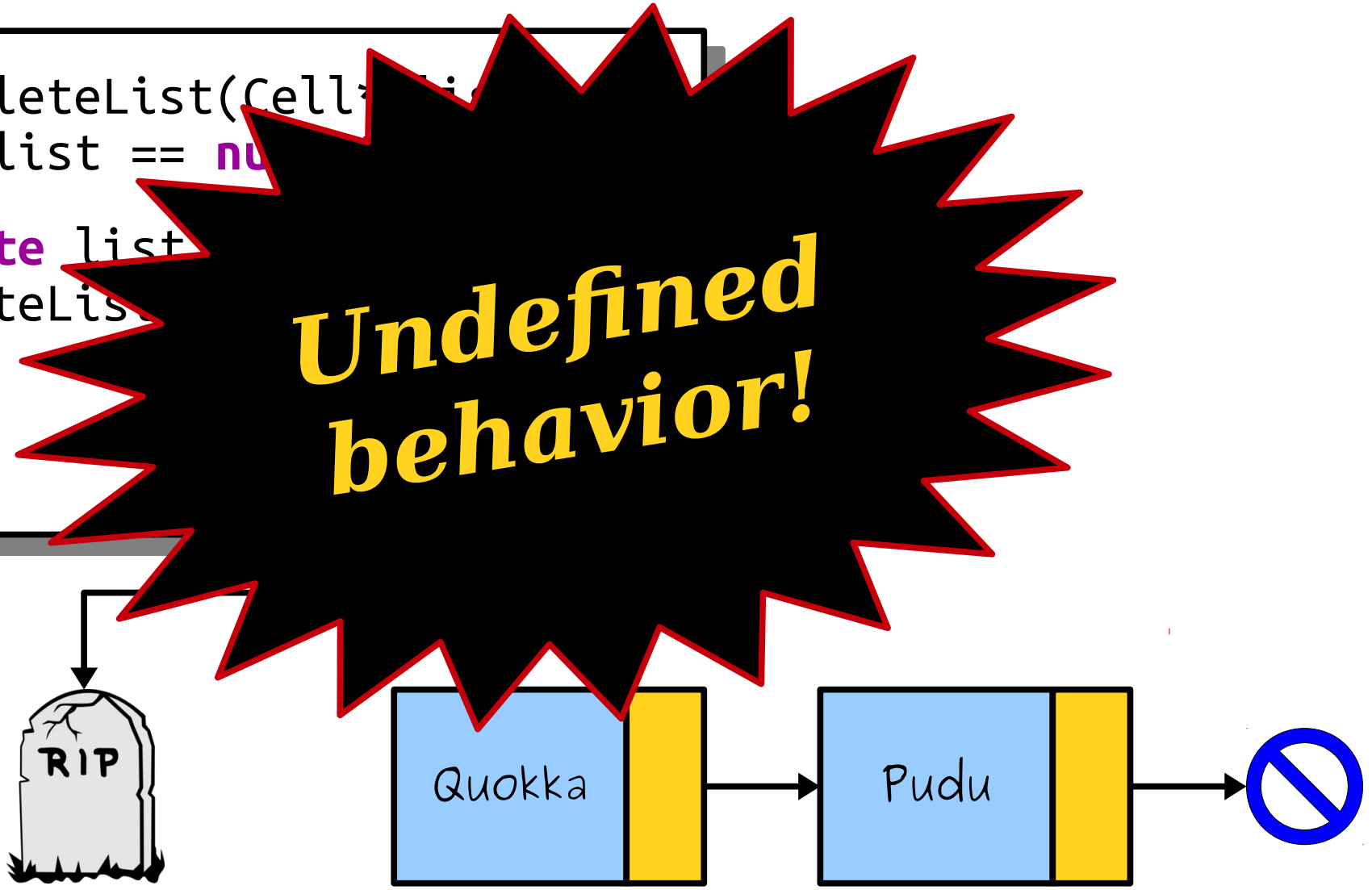


Watch Out!

```
void deleteList(Cell*
    if (list == nu

    delete list
    deleteLis
}
```



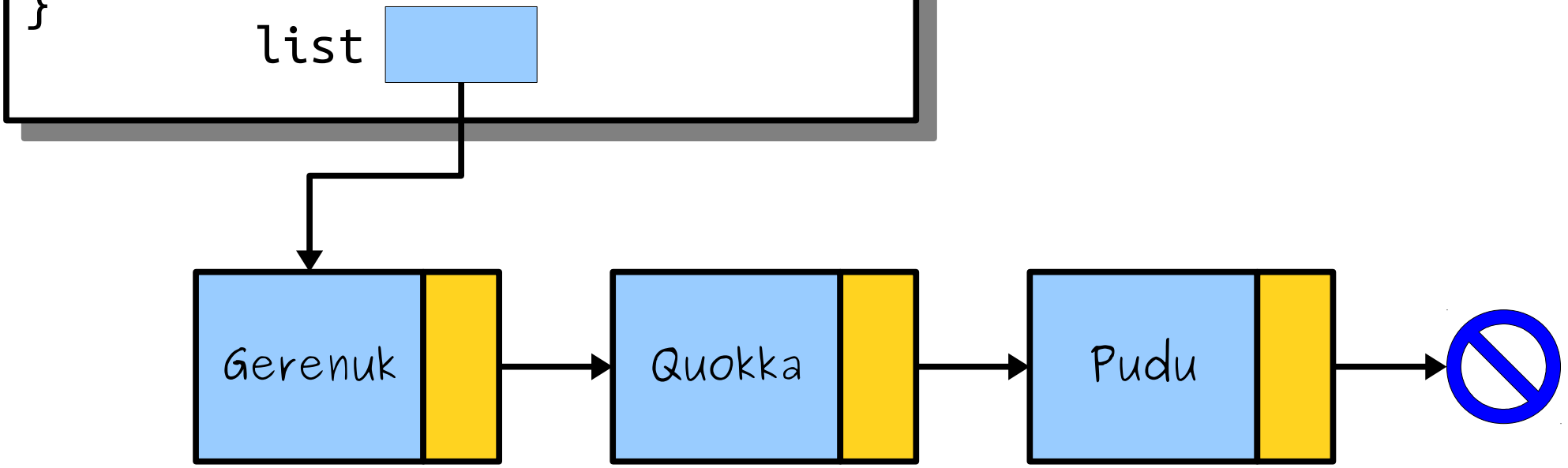
In the Land of C++, we
do not speak to the dead.

What should we do instead?

One Option

```
void deleteList(Cell* list) {
    if (list == nullptr) return;

    Cell* next = list->next;
    delete list;
    deleteList(next);
}
```



One Option

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void deleteList(Cell* list) {
   if (list == nullptr) return;

   Cell* next = list->next;
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   deleteList(next);
}
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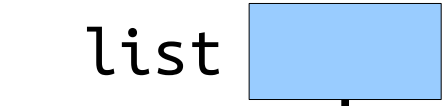

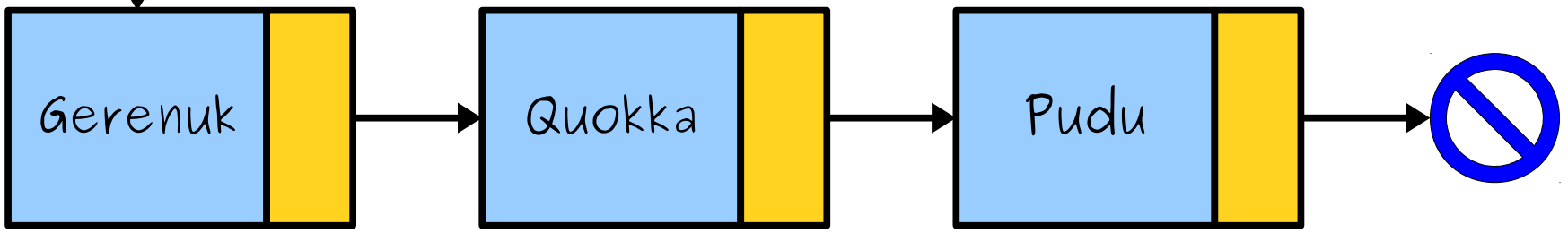

One Option

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void deleteList(Cell* list) {
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    delete list;
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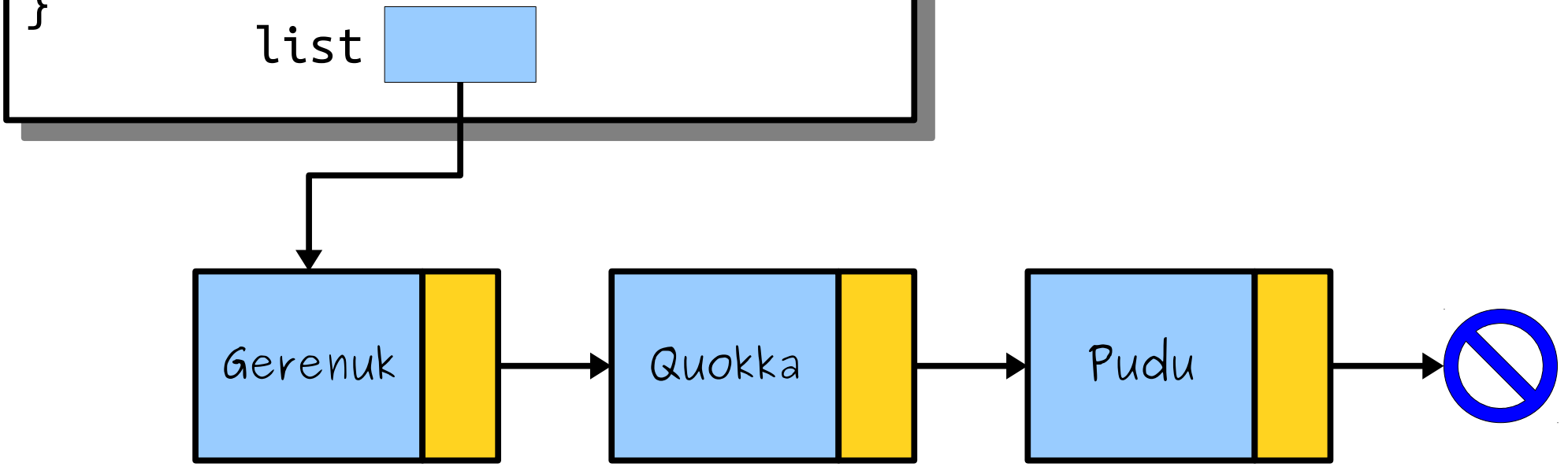
}
```



One Option

```
void deleteList(Cell* list) {
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    Cell* next = list->next;
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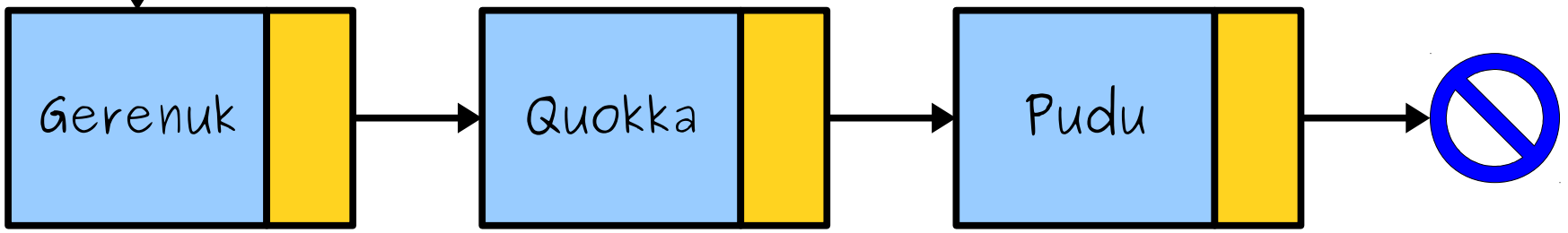
    deleteList(next);
}
```

list next



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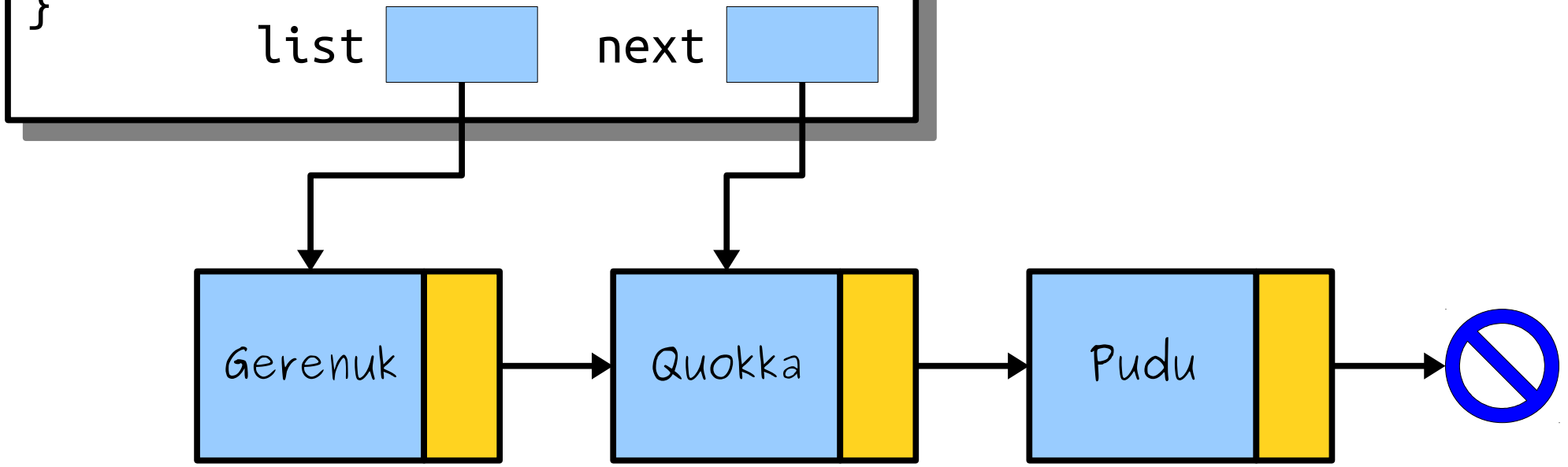

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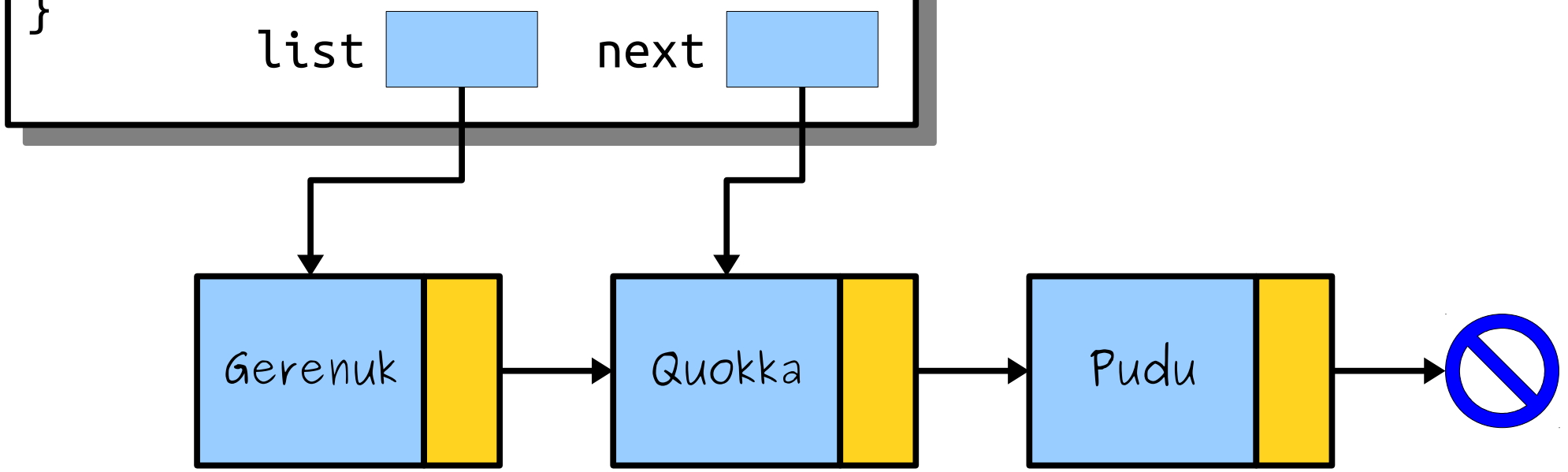
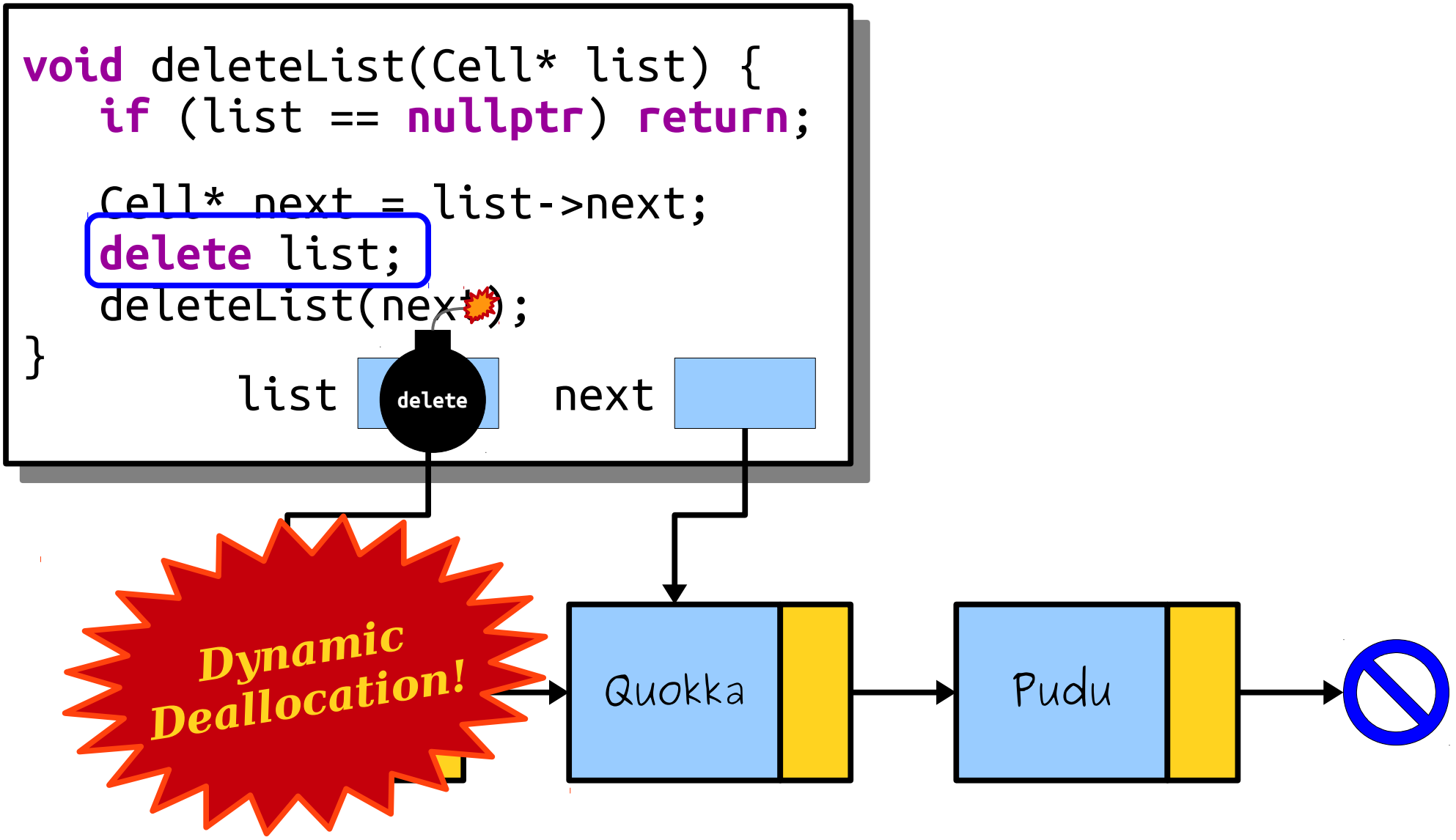


One Option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if (list == nullptr) return;
Cell* next = list->next;
delete list;
deleteList(next);
}
list
delete
next
Dynamic Deallocation!
Quokka
Pudu

One Option

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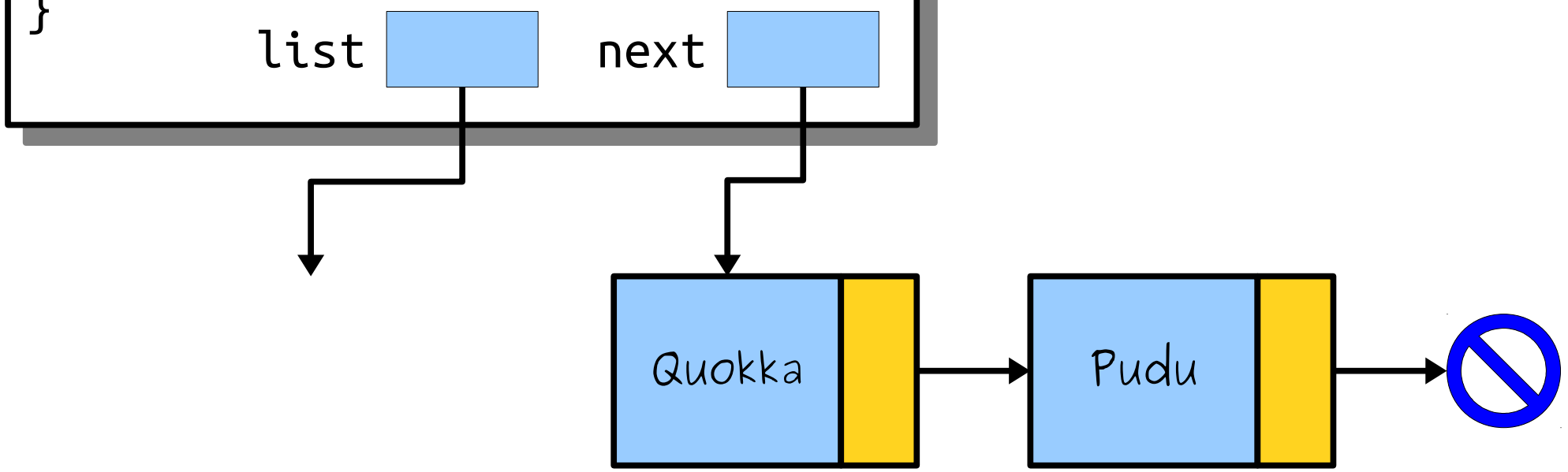
   Cell* next = list->next;
   delete list;
   deleteList(next);
}
```



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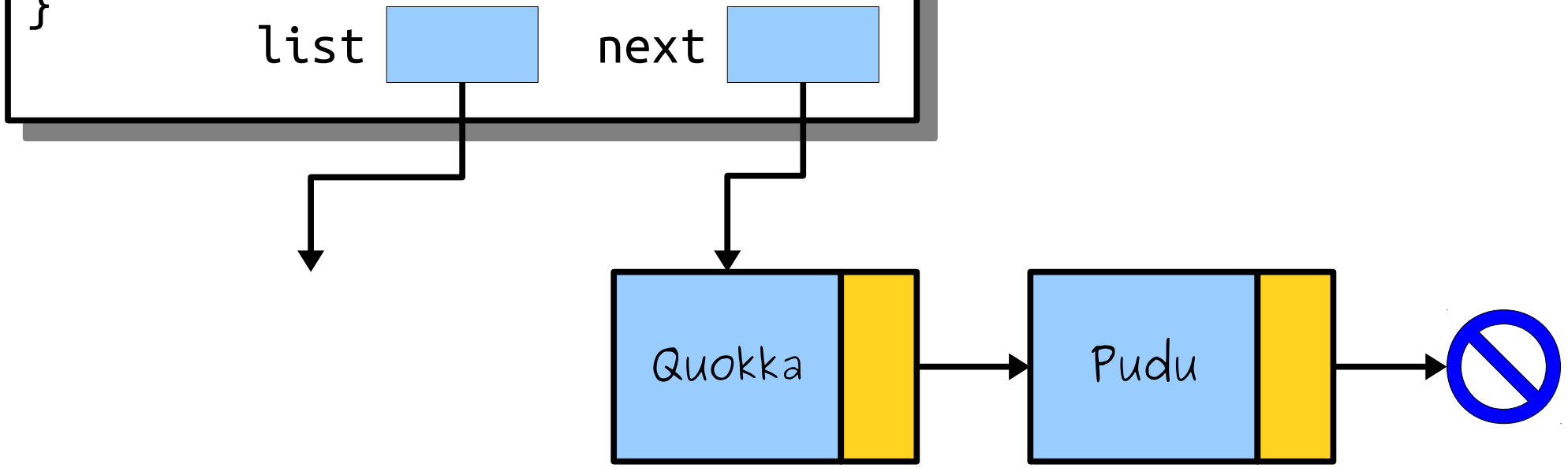

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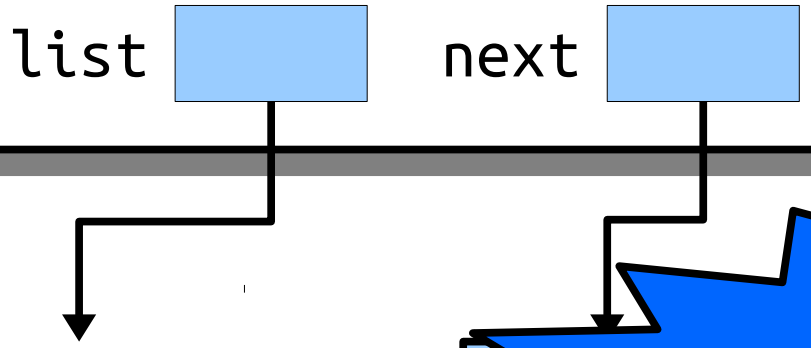

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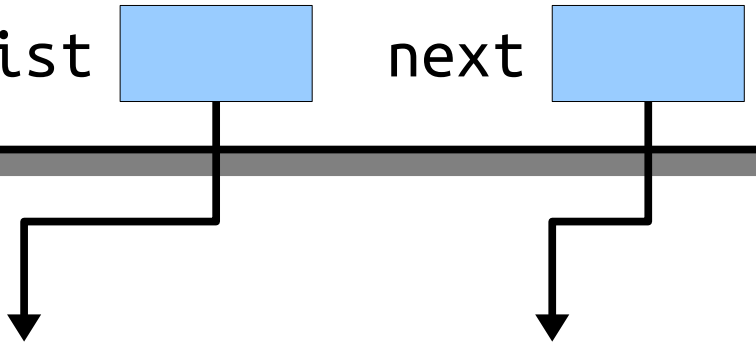

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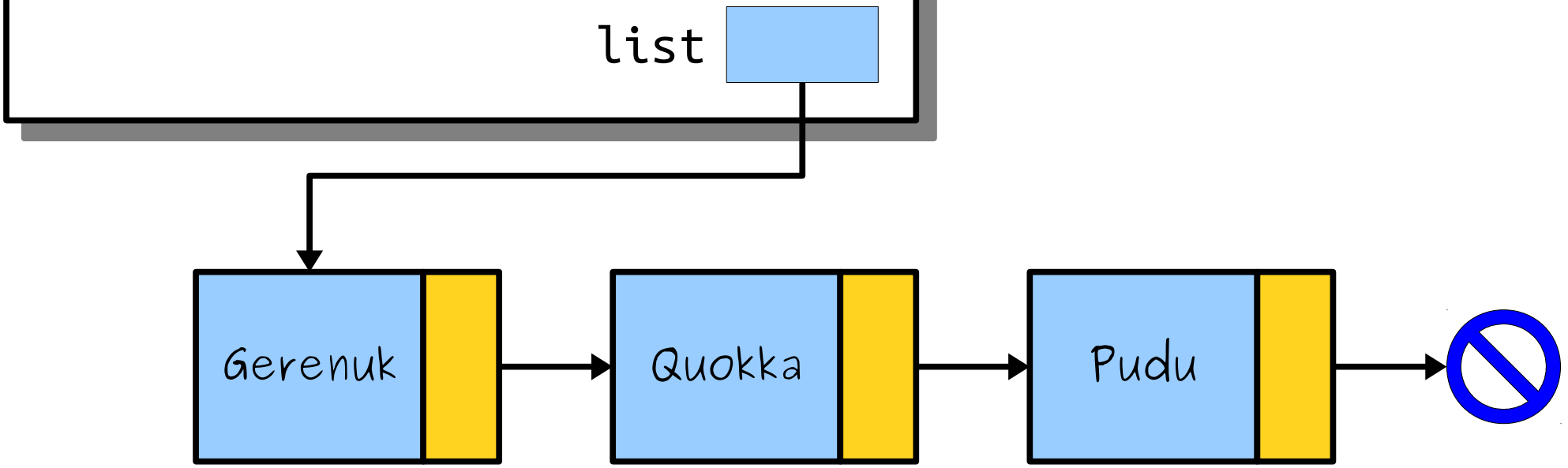

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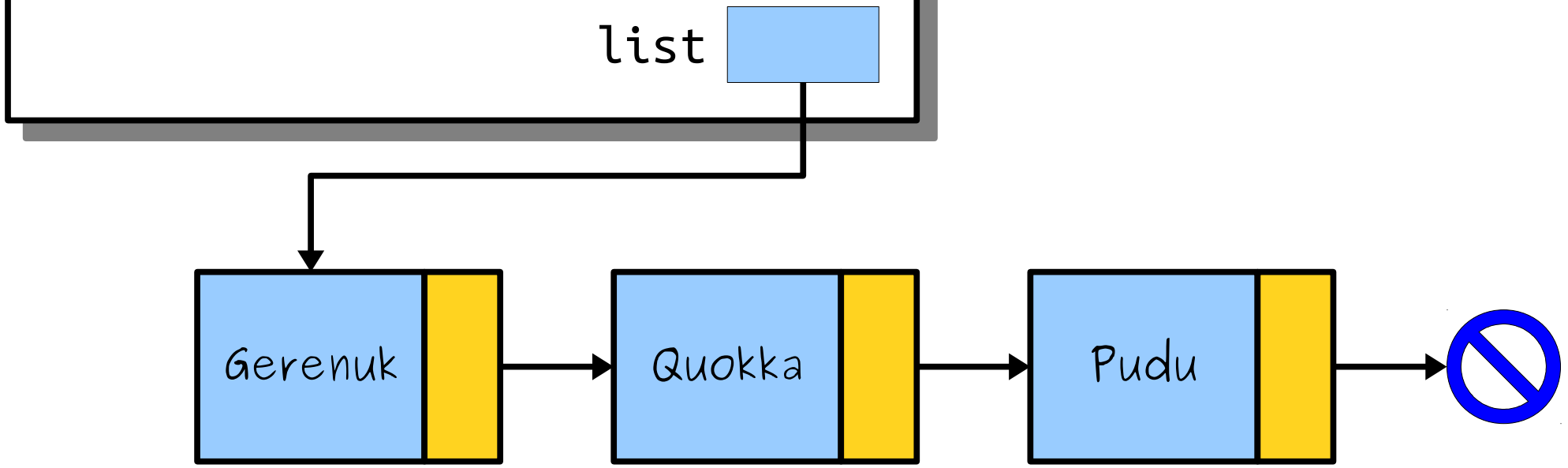

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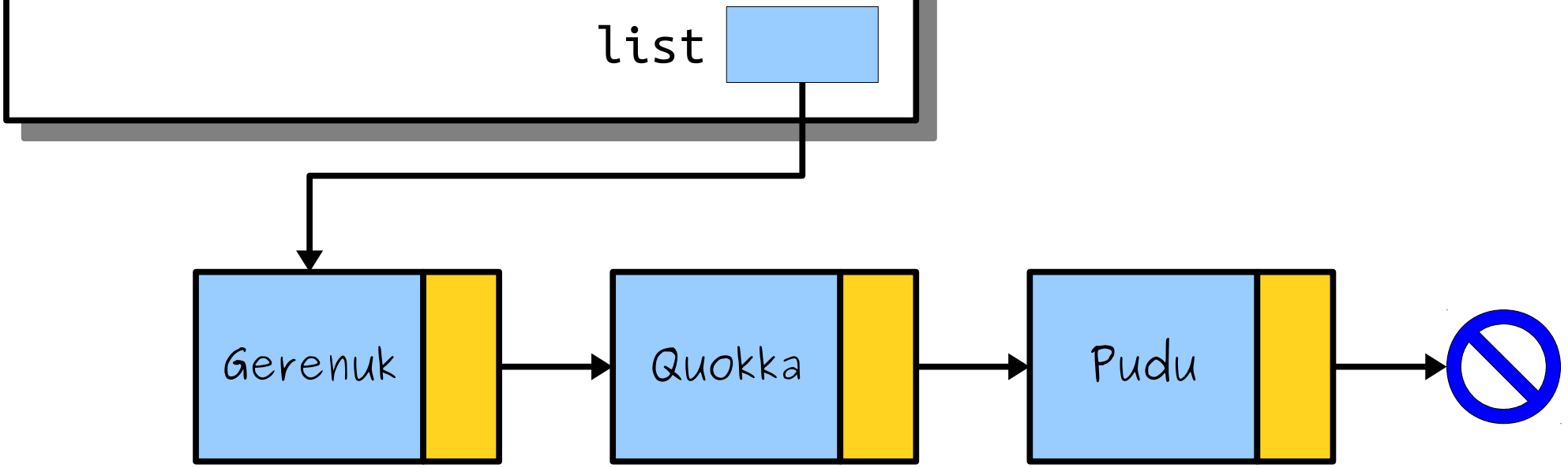

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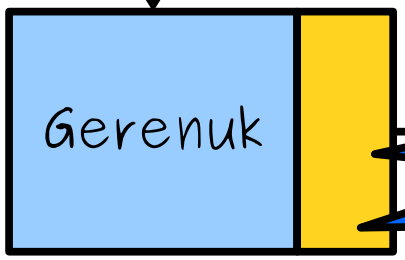
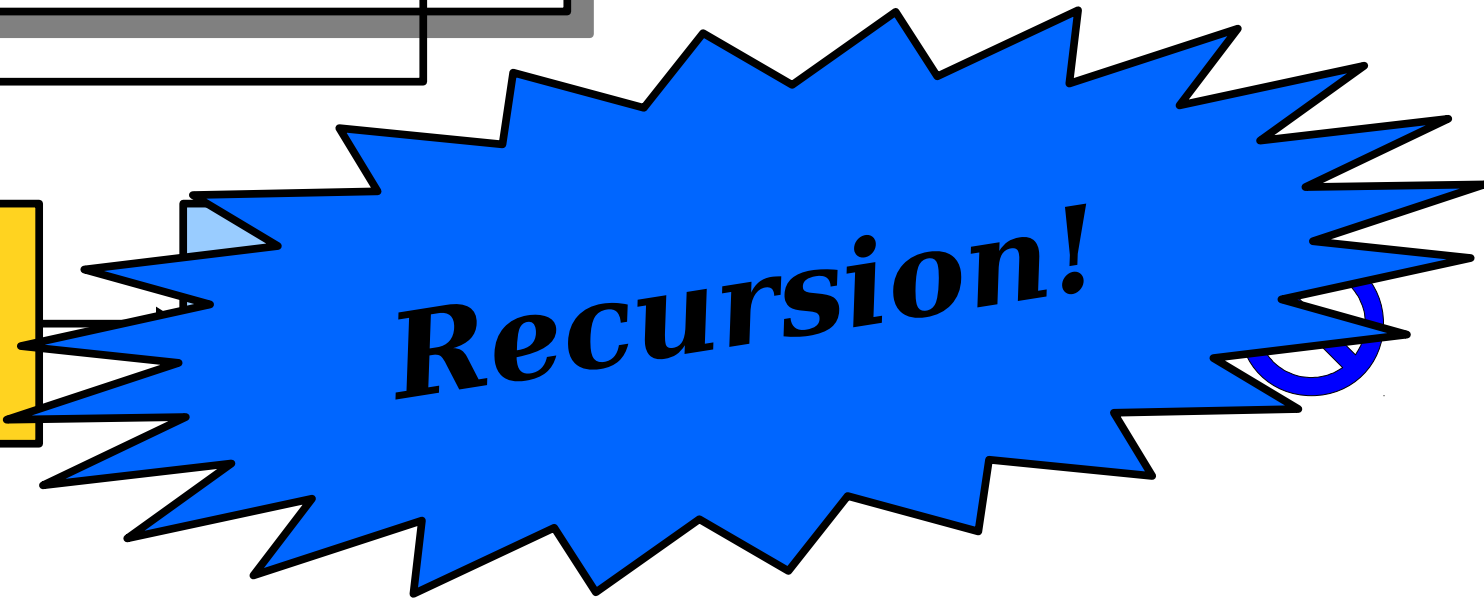
```

list





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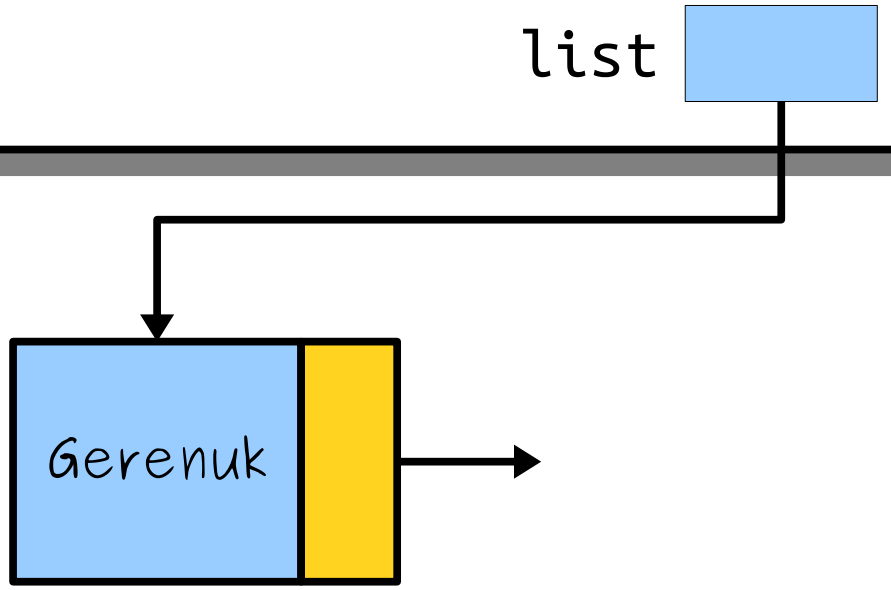

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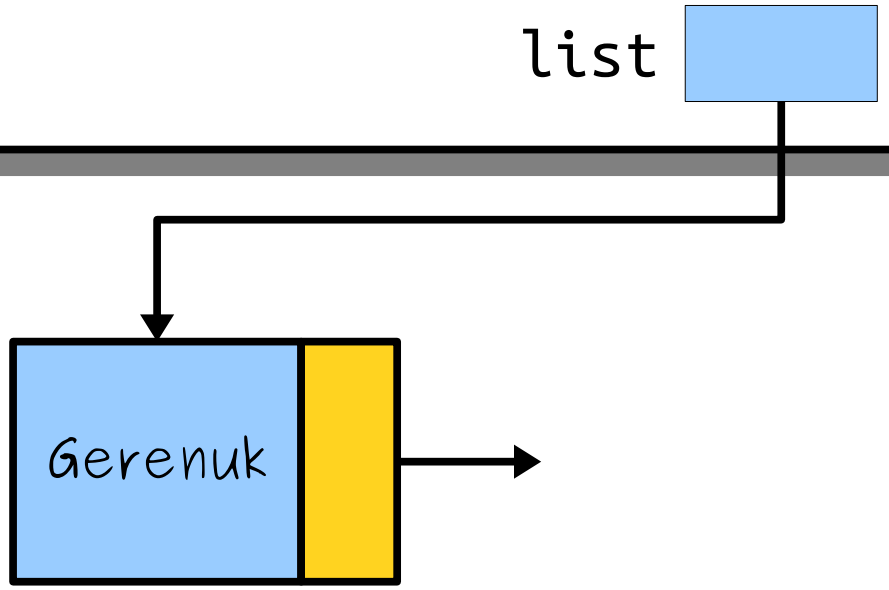

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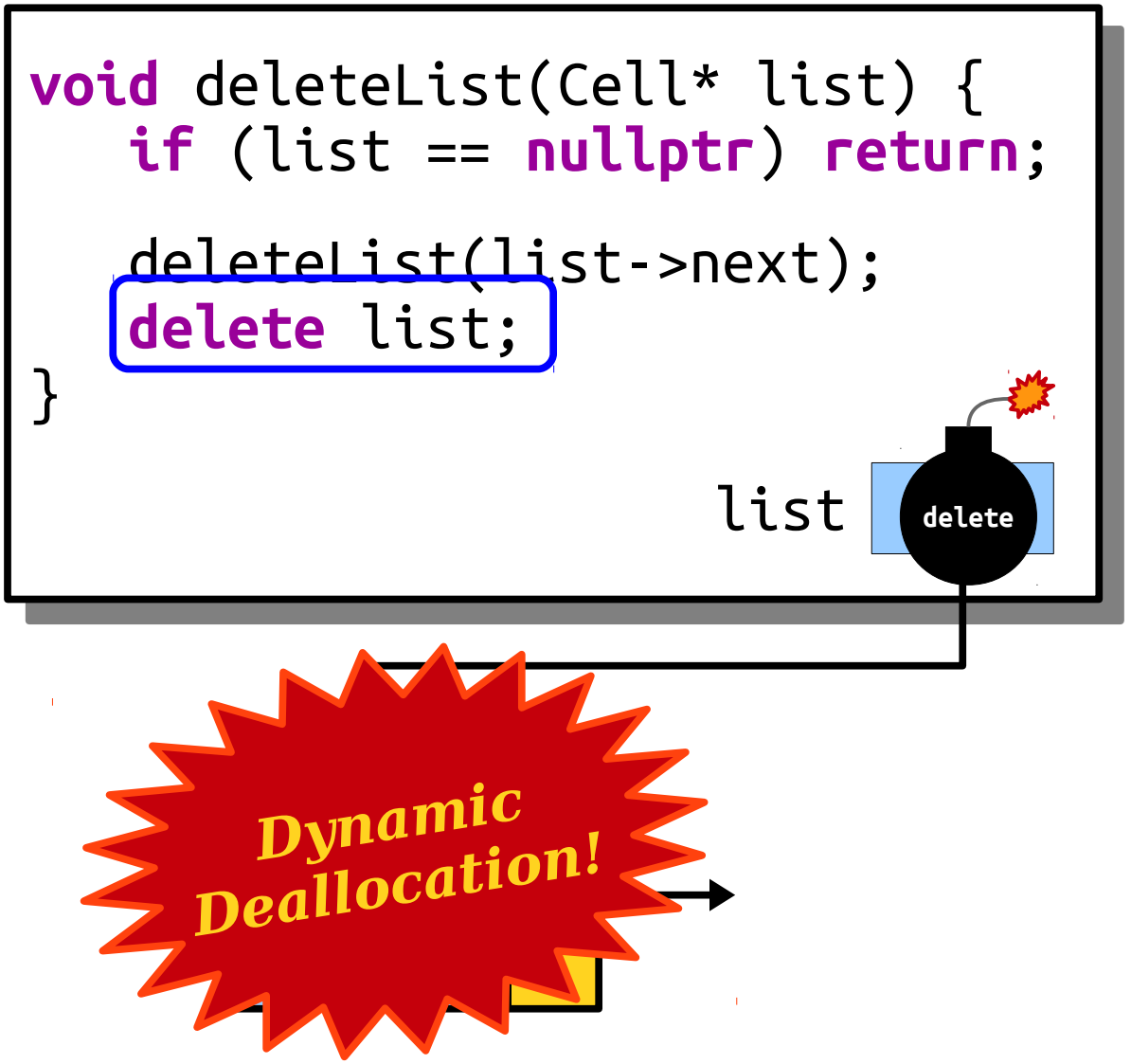

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   deleteList(list->next);
   delete list;
}
```

Your Action Items

- ***Read Chapter 12.1 – 12.3.***
  - There's lots of useful information in there about how to work with linked lists.
- ***Work on Assignment 6.***
  - Aim to complete Linear Probing and to have started Robin Hood hashing by Wednesday.

Next Time

- ***Linked Lists, Iteratively***
  - How do you manually walk a linked list?
- ***Pointers by Reference***
  - Combining two methods of indirection!