Algorithms and Analysis

Lesson 5: *Use Arrays*

Variable length arrays, implementing stacks

Outline

1. **Why Arrays?**
2. Variable Length Arrays
3. Programming Language
4. Implementing Stacks

Use Arrays

- An array is a contiguous chunk of memory
- In C we can create arrays using
  ```
  int *array = new int[20]
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- The array has an access time of $\Theta(1)$
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- Arrays provide a very efficient use of memory
- 95% of the time using arrays is going to give you the best performance, although never use raw arrays!

Disadvantages of Arrays

- Arrays have a fixed length
- Very often we don't know how big an array we want
  - ⋆ E.g. reading words from a file
- Adding or deleting elements from the middle of an array is costly
- Sorted arrays are expensive to maintain
- Arrays don't know how big they are

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Variable Length Arrays

- We want a variable length array
- Initially a variable length array would have length zero
- We should be able to
  - ⋆ Add an element to an array
  - ⋆ Access any element in the array
  - ⋆ Change an element
  - ⋆ Delete elements
  - ⋆ Know how many elements we have

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  - ⋆ random access `array[i]`
  - ⋆ **`int`** `size()`
- It would be useful if it resized
- It would be great to have some algorithms (e.g. sort) that can be run on a list

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- We need to distinguish between
  - ⋆ the number of elements in the list `size()`
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- If the number of elements grows larger than the capacity then we need to increase the capacity

Initial Capacity

- We could prevent resizing arrays by using a huge initial capacity
- However, how big is big enough?
- What happens when we have an array of arrays?
- Memory like time is resource we should care about
- In an analogy with **time complexity** we also care about **space complexity** (i.e. how much memory we need)
- If we want to store n elements it is reasonable to expect that we use $c\,n$ bits of memory where we want to keep c small

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Resizing Memory

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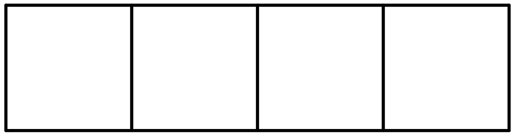

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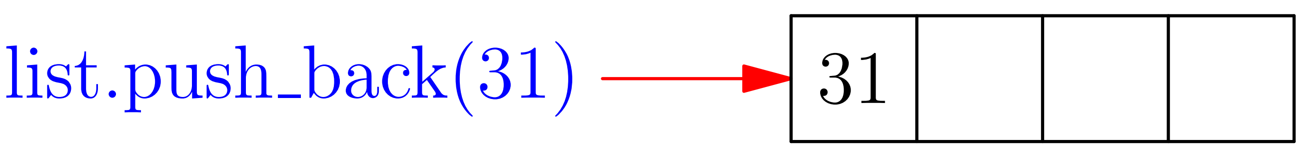

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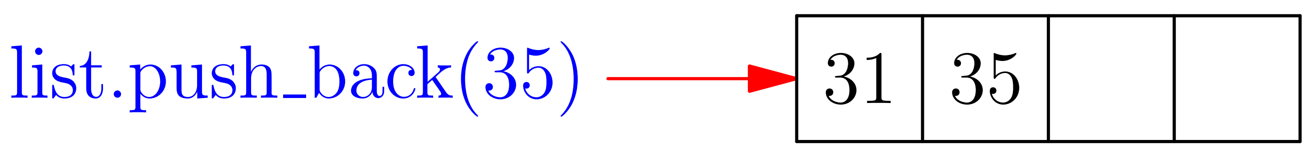

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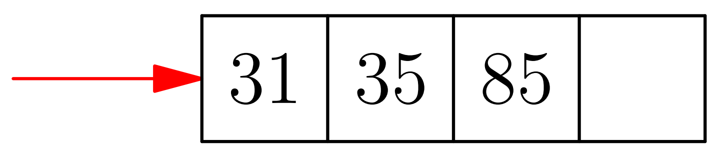
list.push_back(85)



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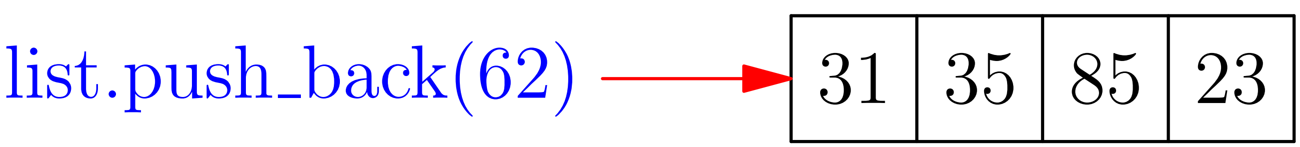

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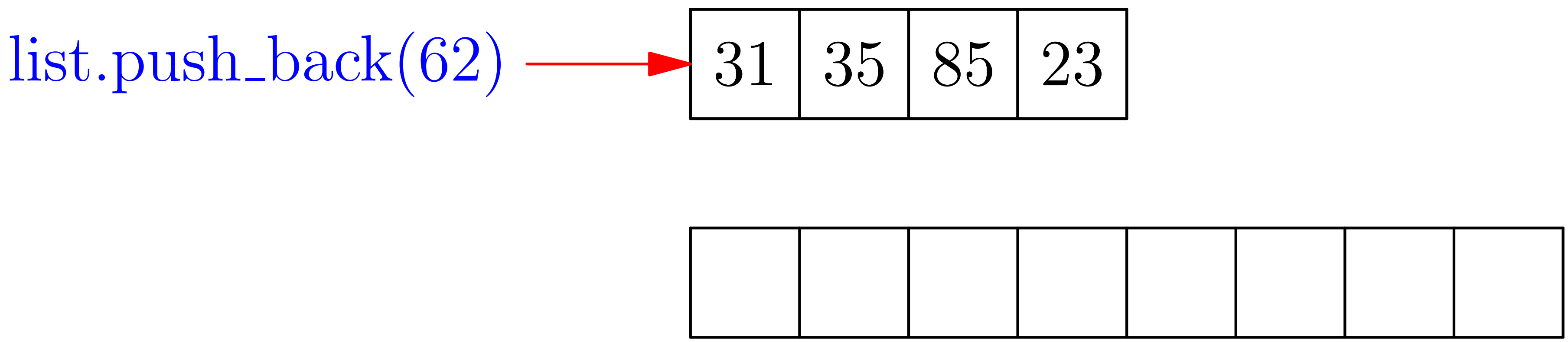
  - ⋆ create a new array with double the capacity of the old array



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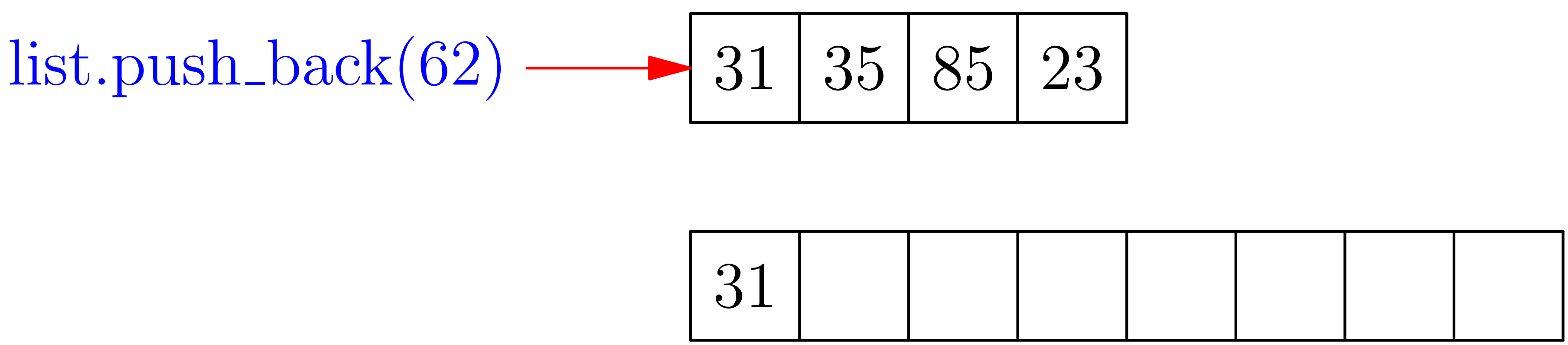

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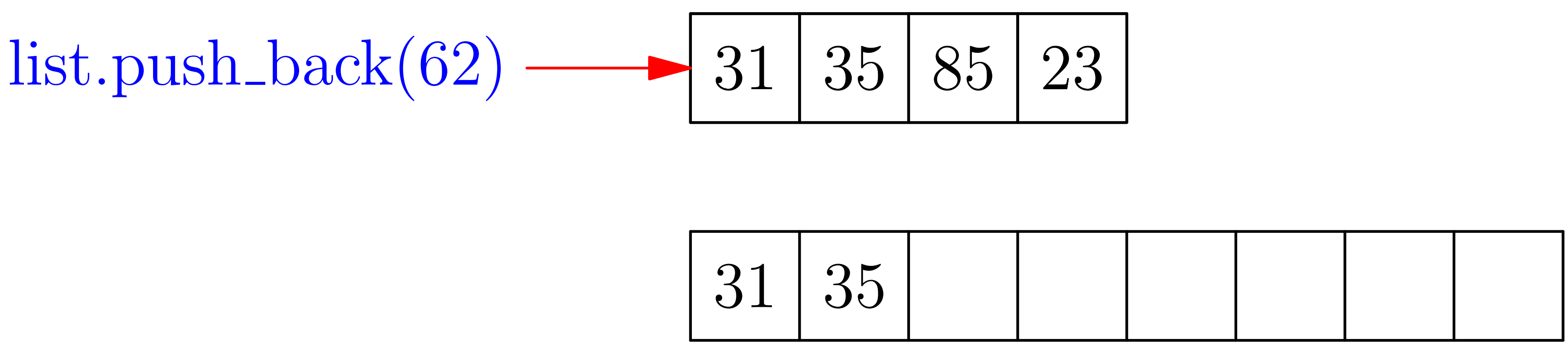

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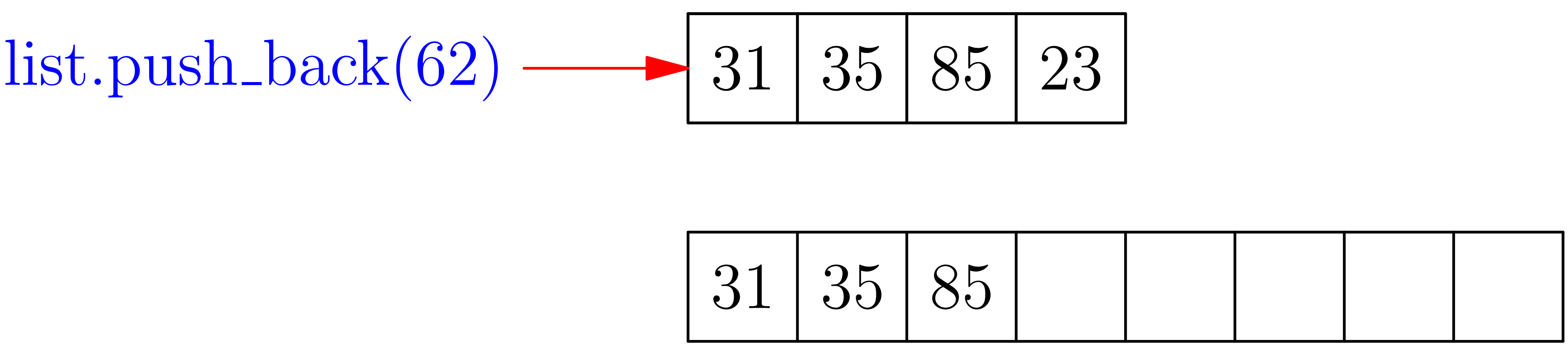

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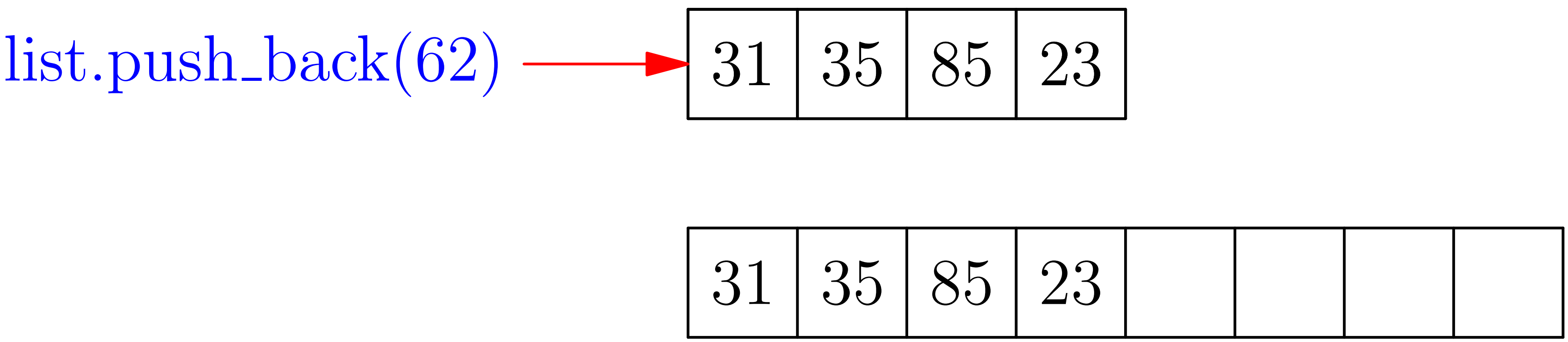

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Amortised Time Analysis

- How efficient is resizing?
- Most `push_back(elem)` operations are $\Theta(1)$
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- Adding to a full array is slow but it is **amortised** by other quick adds

  amortised: effect of a single operations 'deadened' by other operations

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- If we have an initial capacity of 10 and add 100 elements then the number of operations needed is
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  - ⋆ **`new int`**`[]`: 4

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- If we have an initial capacity of 10 and add 100 elements then the number of operations needed is
  - ⋆ adds: 100
  - ⋆ copies: $10+20+40+80=150$
  - ⋆ **`new int[]`**: 4
- 250 adds and copies operations + 4 **`new`** operations

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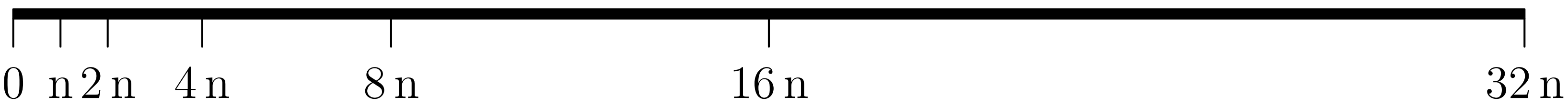
- We must perform m copies where



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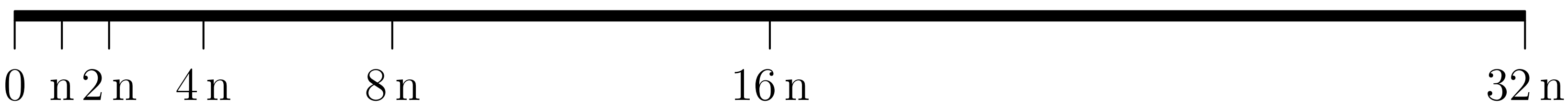

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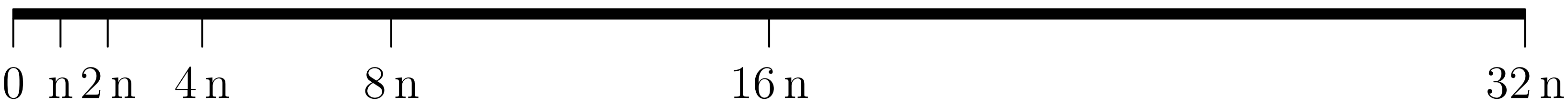

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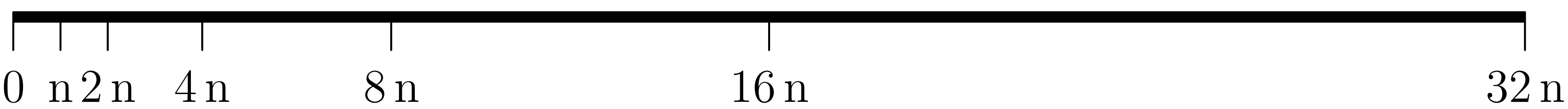

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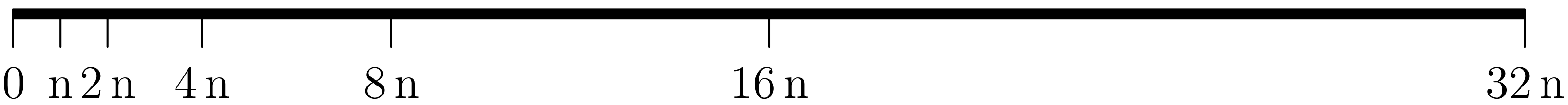

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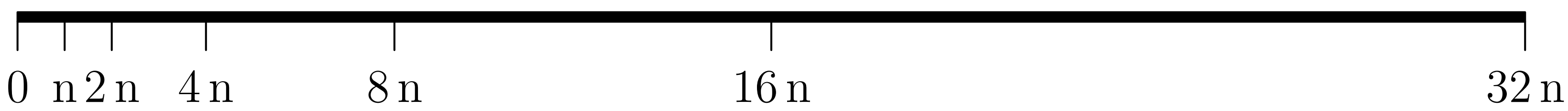

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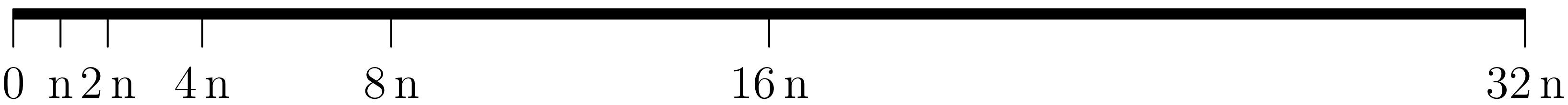

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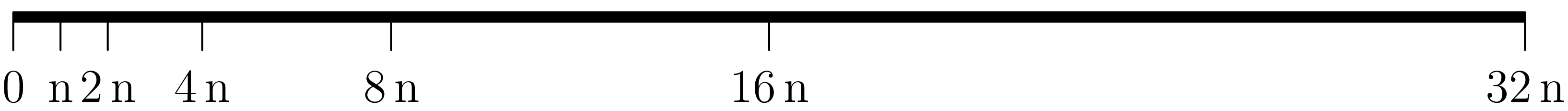

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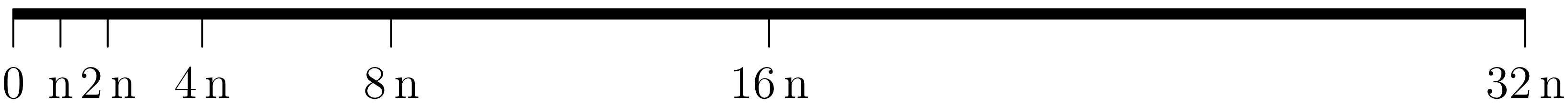

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- `vector<T>` is very useful and very fast for lots of things
- But if you try to insert or delete an element anywhere other than the end then you have to shove all the subsequent elements one space forward
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Outline

1. Why Arrays?
2. Variable Length Arrays
3. **Programming Language**
4. Implementing Stacks

Computer Languages

- Different computer languages are designed for different roles and have different advantages and disadvantages
- **C++** was designed to be fast (as fast as C)
- **Java** was designed to be vary safe (avoiding lots of bugs)
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Problems with C++

- Amongst a number of issues that make C++ dangerous are
  - ⋆ Memory management
  - ⋆ Writing to parts of memory that you should not
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- In C++ this is your responsibility
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Writing over Memory

- In C++ the following will compile and run

```
int *array = new int[4];
int *a = new int[2];
double *darray = new double[4];
array[4] = 4;
```

- However `array[4]` has not been assigned (unlike `array[0]`, `array[1]`, `array[2]` and `array[3]`)

- The memory on the heap corresponding to the address of `array[4]` might have been assigned to `a[0]` in which case you may inadvertently have set `a[0]` to 4 leading to the program not doing what you want

- It might be that you have put an `int` into `darray[0]` which will then crash the system when you read `darray[0]`

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- These are really hard problems to debug because where the program goes wrong or crashes can be very far from the assignment that caused the error
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- By default C++ doesn't even for data structures—making this check slows down random access
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Follow Programming Idioms

- Using common data structures and following common idioms will prevent most errors

```
int n = 5;
vector<int> array(n);

for(int i=0; i<array.size(); ++i) {
  array[i] = i;
}

for(auto pt=array.begin(); pt != array.end(); ++pt){
  *pt *= 2
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for(int& element: array) {
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4. **Implementing Stacks**

Stacks

- Lets look at implementing a stack
- Remember a stack has methods
  - `push(Object )`
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template <typename T>
class MyStack
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private:
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public:
  void push(const T& obj) {stack.push_back(obj);}

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- I can make `MyStack<T>` as efficient as `vector<T>` by inlining function calls

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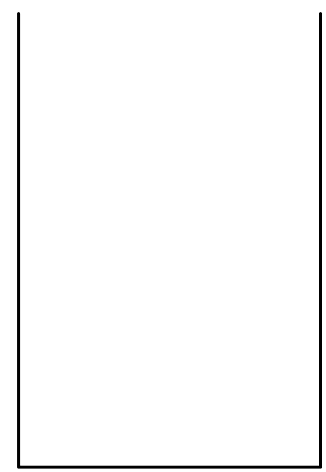

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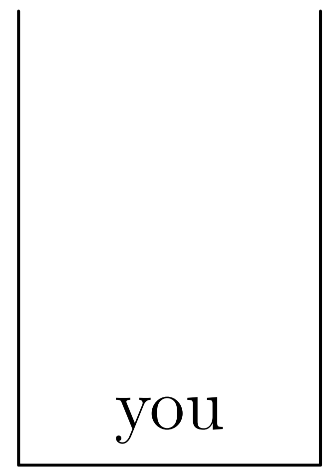

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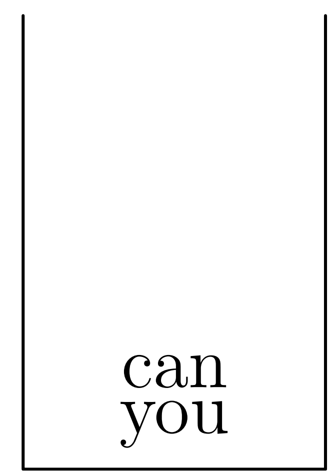

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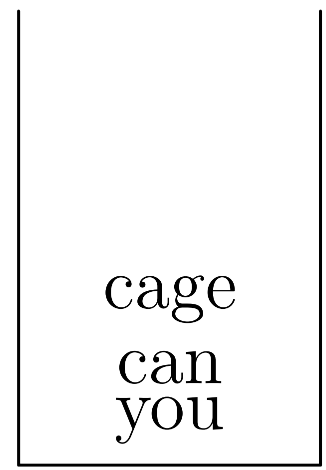

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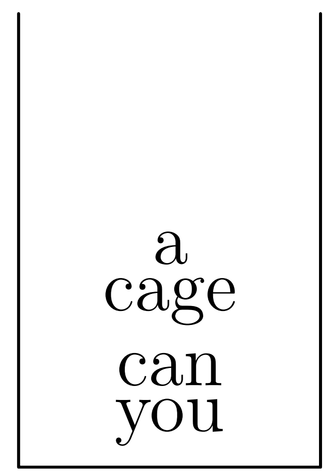

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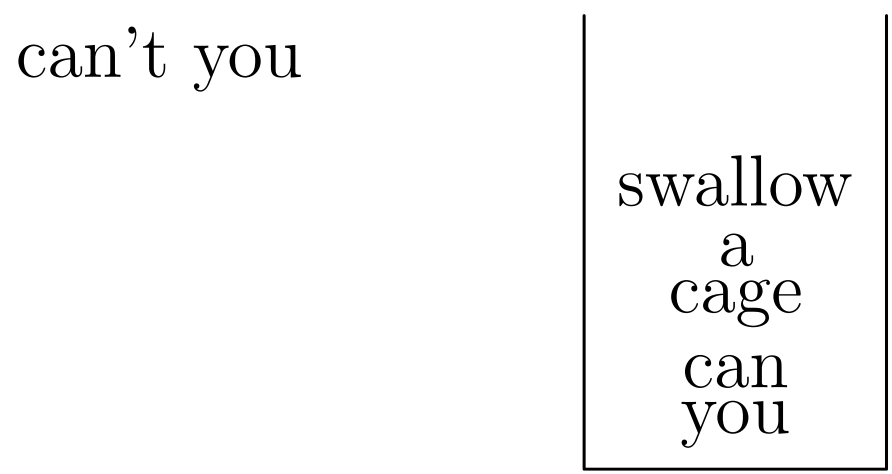

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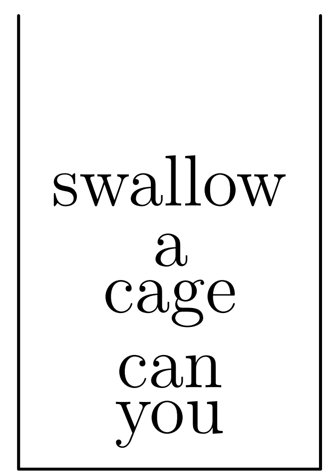

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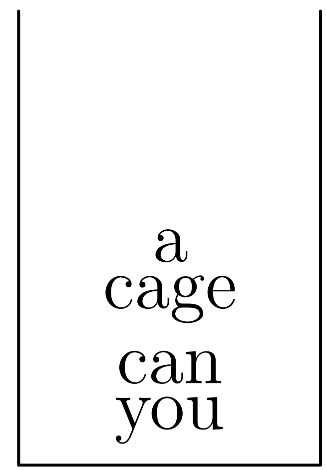

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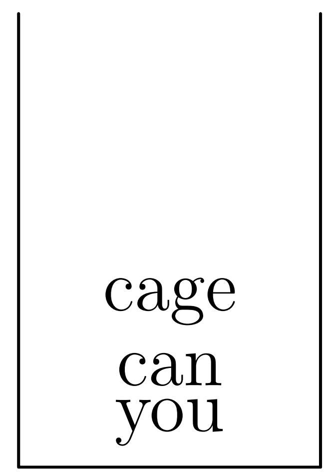

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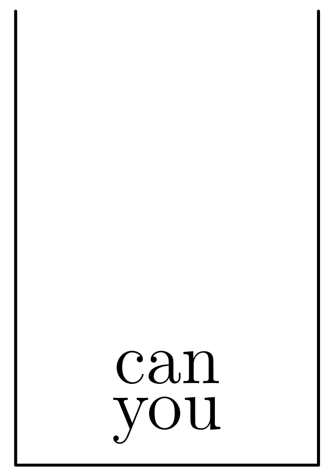

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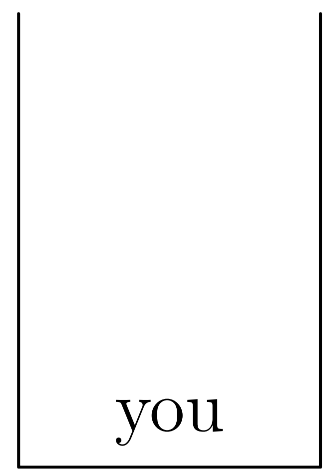

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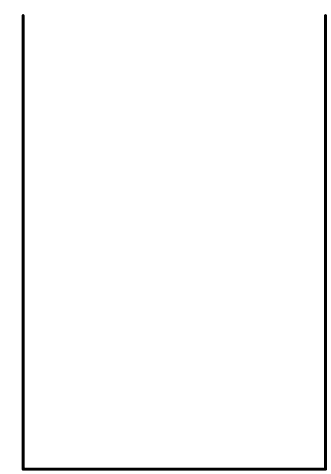

Reversing Strings in File

```
#include <stack>
#include <iostream>
#include <fstream>
using namespace std;

int main(int argc, char *argv[]) {
  ifstream in(argv[1]);

  stack<string> stack;

  string word;
  while (in >> word)
    stack.push(word);

  while(!stack.empty()) {
      cout << stack.top() << ' ';
      stack.pop();
  }
}
```

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- Resizing an array is not that costly
- insertion and deletion are expensive, $O(n)$
- Arrays are often the simplest way to implement many other data structures, e.g. stacks
- Use (dynamically re-sizable) arrays (vector¡T¿) frequently!

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