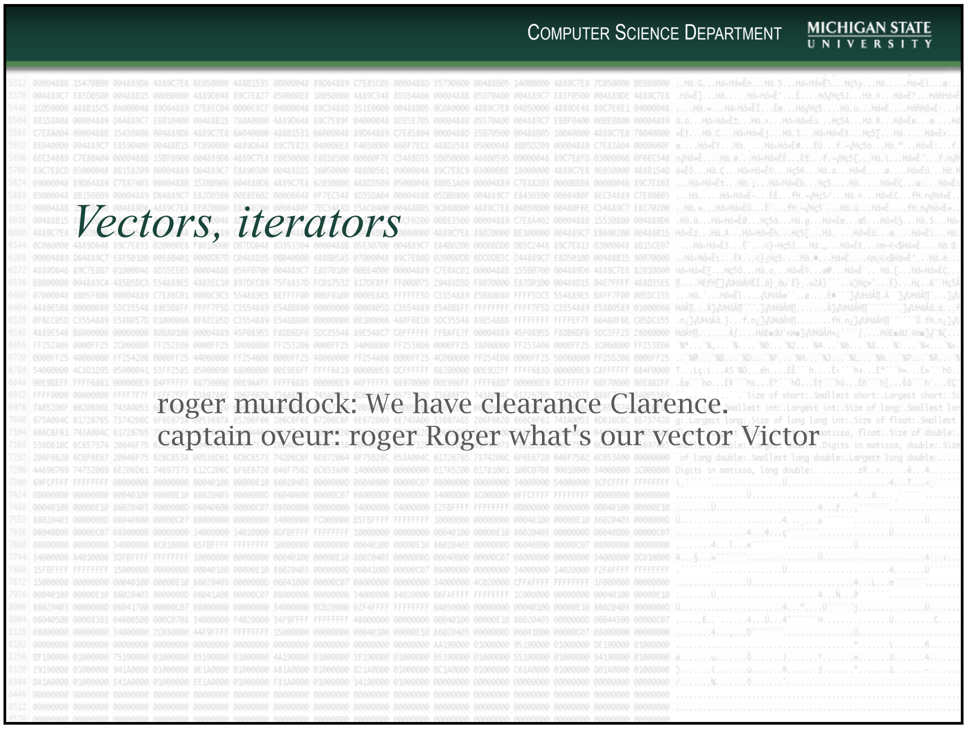
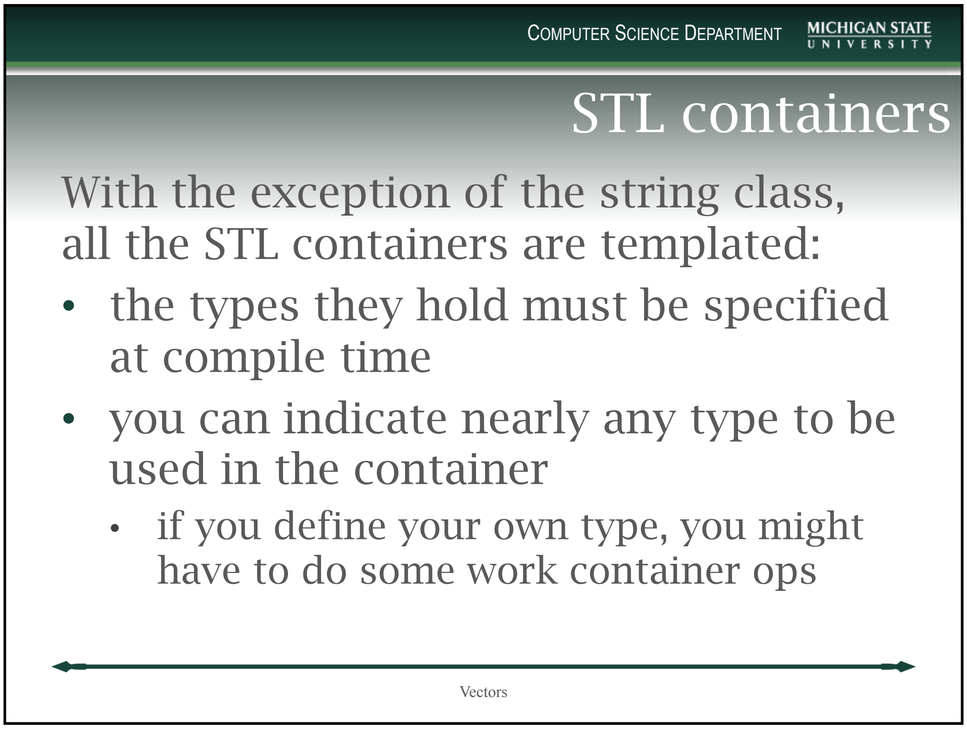


COMPUTER SCIENCE DEPARTMENT

MICHIGAN STATE UNIVERSITY

Vectors, iterators

roger murdock: We have clearance Clarence.
captain oveur: roger Roger what's our vector Victor



COMPUTER SCIENCE DEPARTMENT

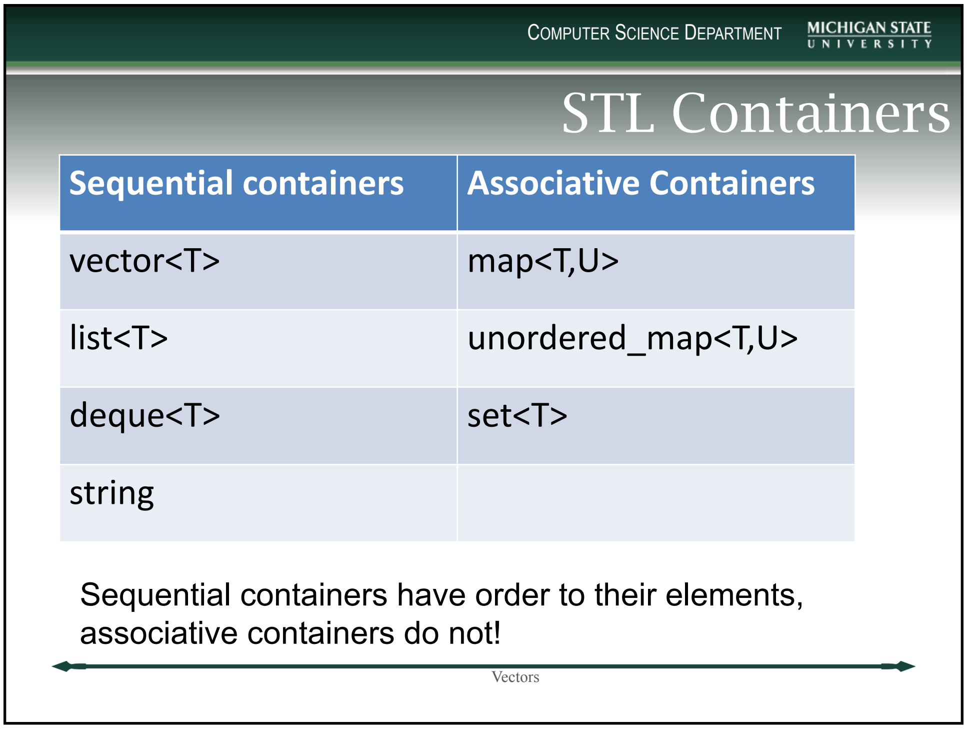
MICHIGAN STATE UNIVERSITY

STL containers

With the exception of the string class, all the STL containers are templated:

- the types they hold must be specified at compile time
- you can indicate nearly any type to be used in the container
  - if you define your own type, you might have to do some work container ops

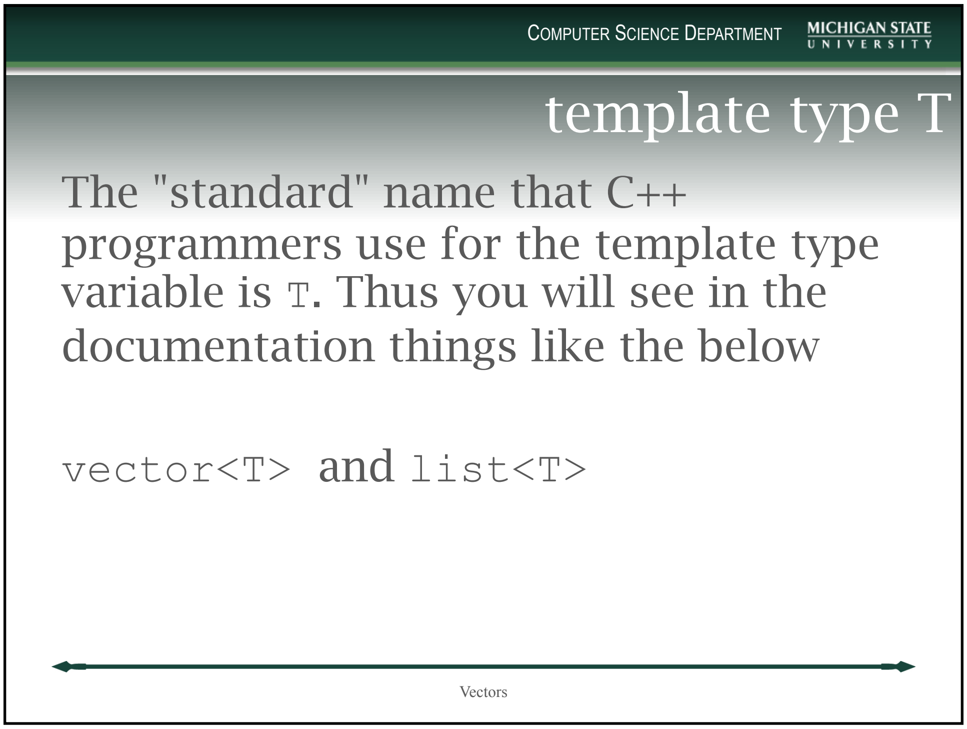
Vectors



STL Containers

Sequential containers	Associative Containers
vector<T>	map<T,U>
list<T>	unordered_map<T,U>
deque<T>	set<T>
string	

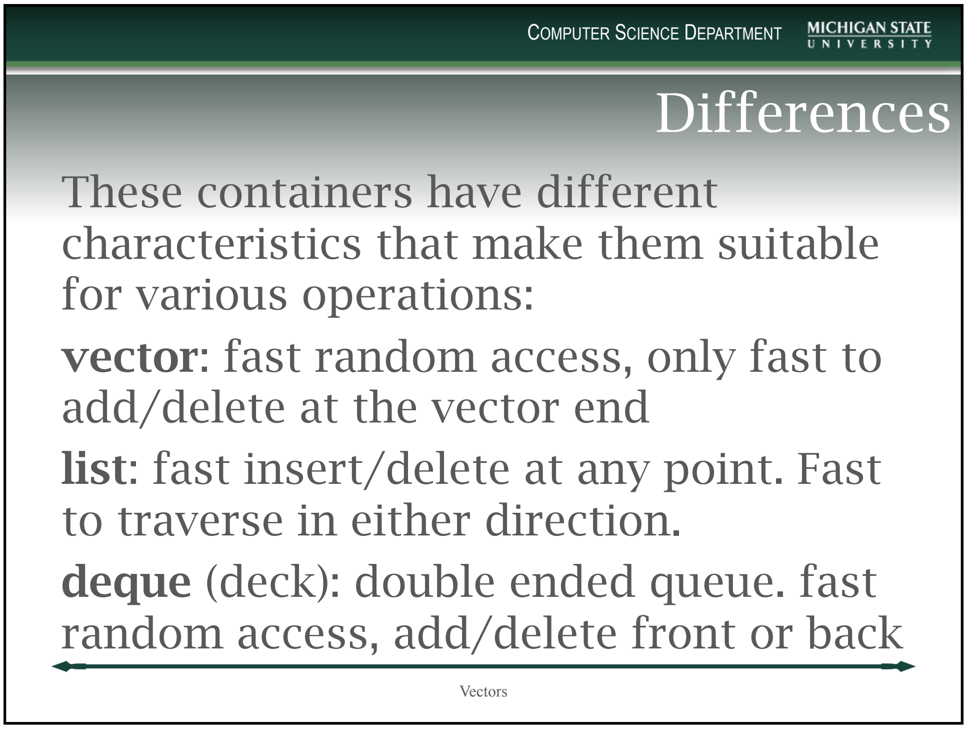
Sequential containers have order to their elements, associative containers do not!



template type T

The "standard" name that C++ programmers use for the template type variable is `T`. Thus you will see in the documentation things like the below

`vector<T>` and `list<T>`



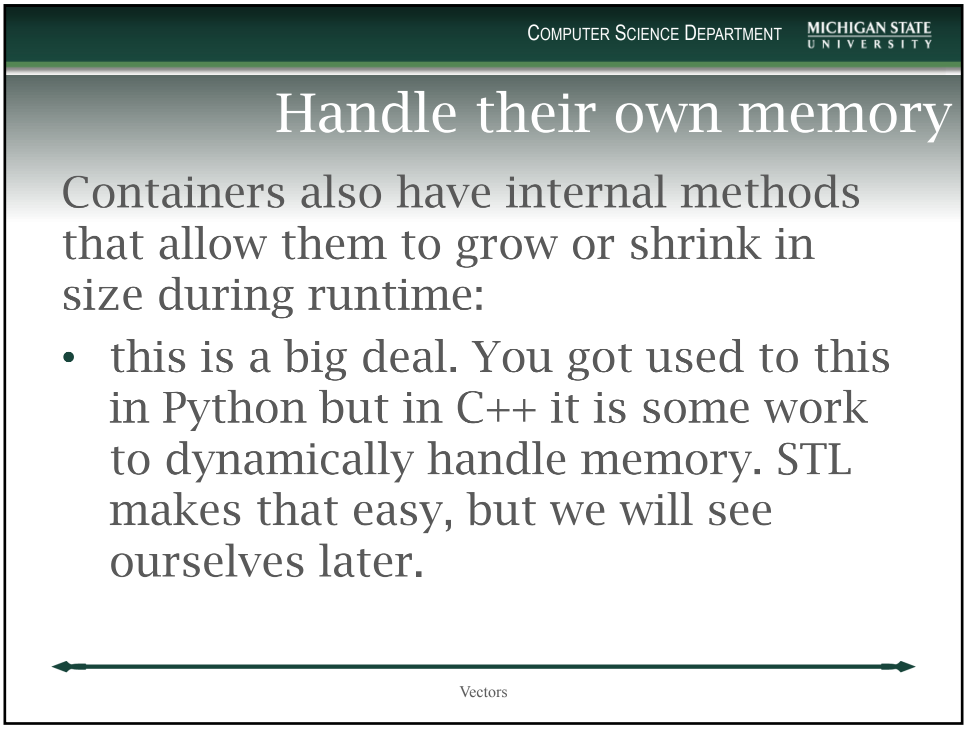
Differences

These containers have different characteristics that make them suitable for various operations:

vector: fast random access, only fast to add/delete at the vector end

list: fast insert/delete at any point. Fast to traverse in either direction.

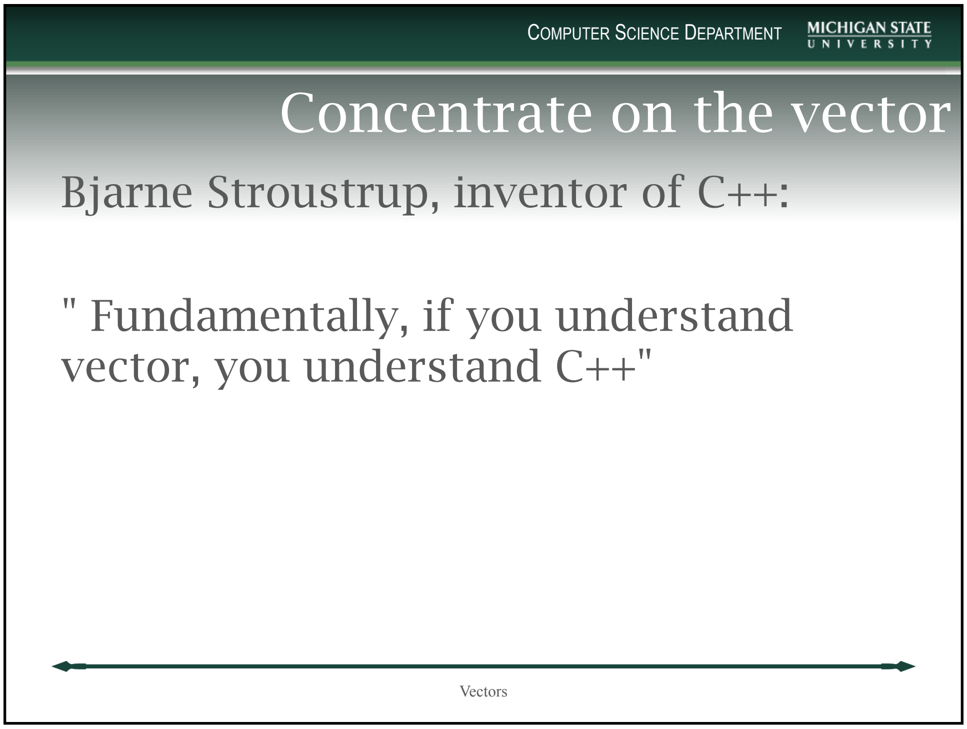
deque (deck): double ended queue. fast random access, add/delete front or back



Handle their own memory

Containers also have internal methods that allow them to grow or shrink in size during runtime:

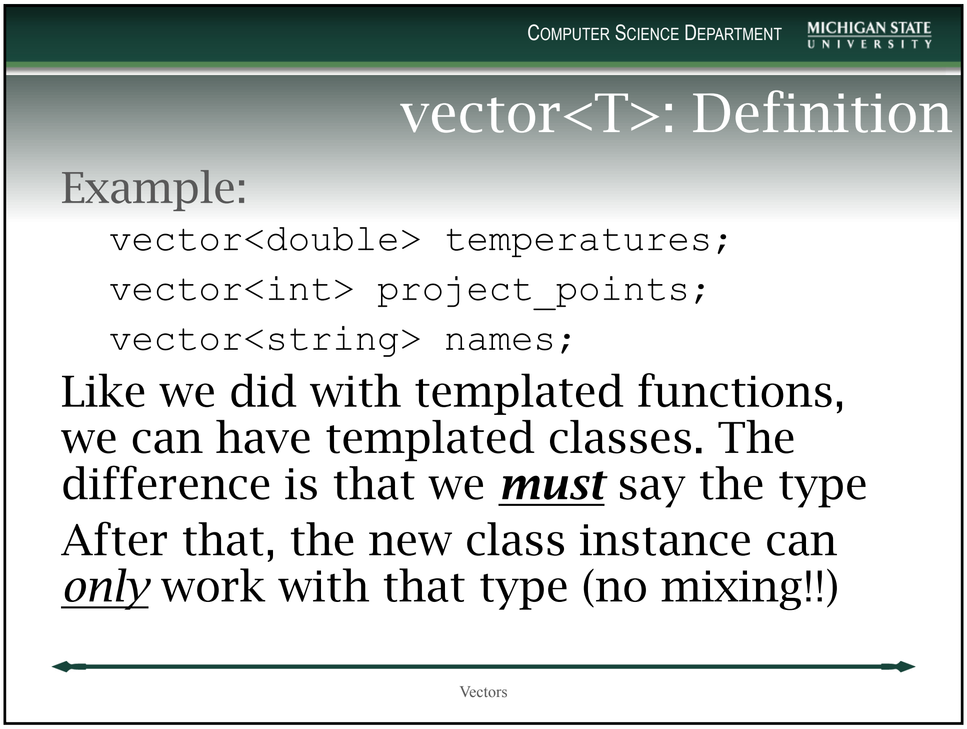
- this is a big deal. You got used to this in Python but in C++ it is some work to dynamically handle memory. STL makes that easy, but we will see ourselves later.



Concentrate on the vector

Bjarne Stroustrup, inventor of C++:

" Fundamentally, if you understand vector, you understand C++"



vector<T>: Definition

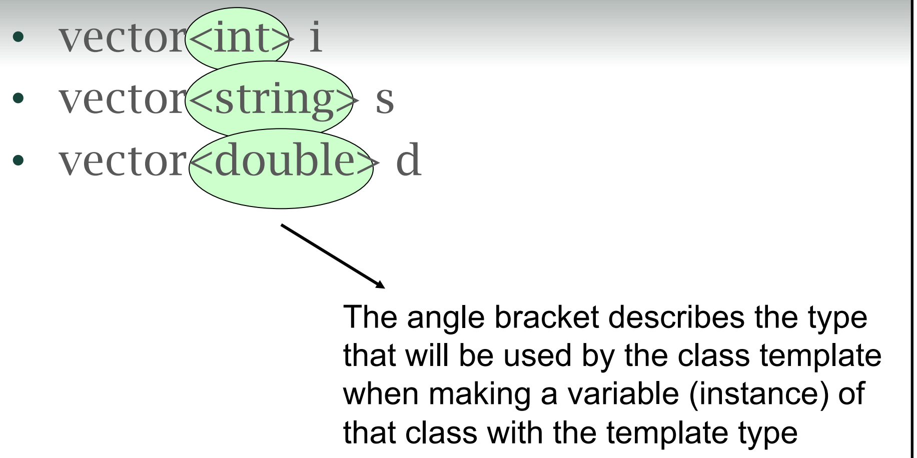
Example:

```
vector<double> temperatures;
vector<int> project_points;
vector<string> names;
```

Like we did with templated functions, we can have templated classes. The difference is that we ***must*** say the type

After that, the new class instance can *only* work with that type (no mixing!!)

Example

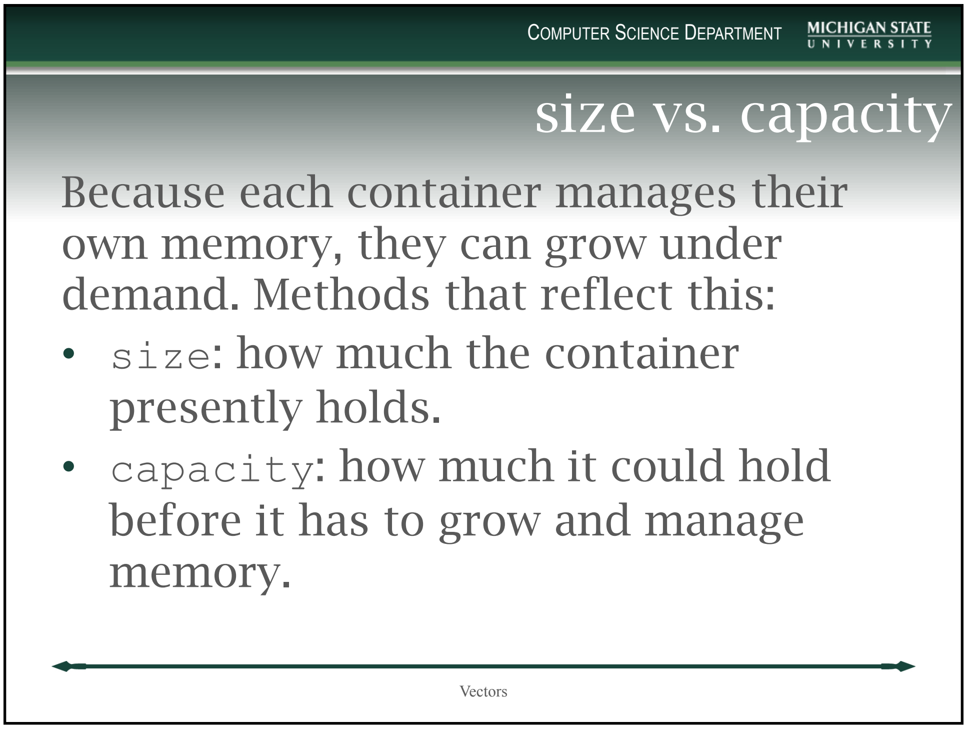


- vector<int> i
- vector<string> s
- vector<double> d

The angle bracket describes the type that will be used by the class template when making a variable (instance) of that class with the template type

Remember, class template is a pattern

- The class definition has every type represented by a variable (for example, T)
- When you make an variable/instance of the class, instantiate the class with the T type substituted for the T type
- The class instance is made with all the types substituted properly



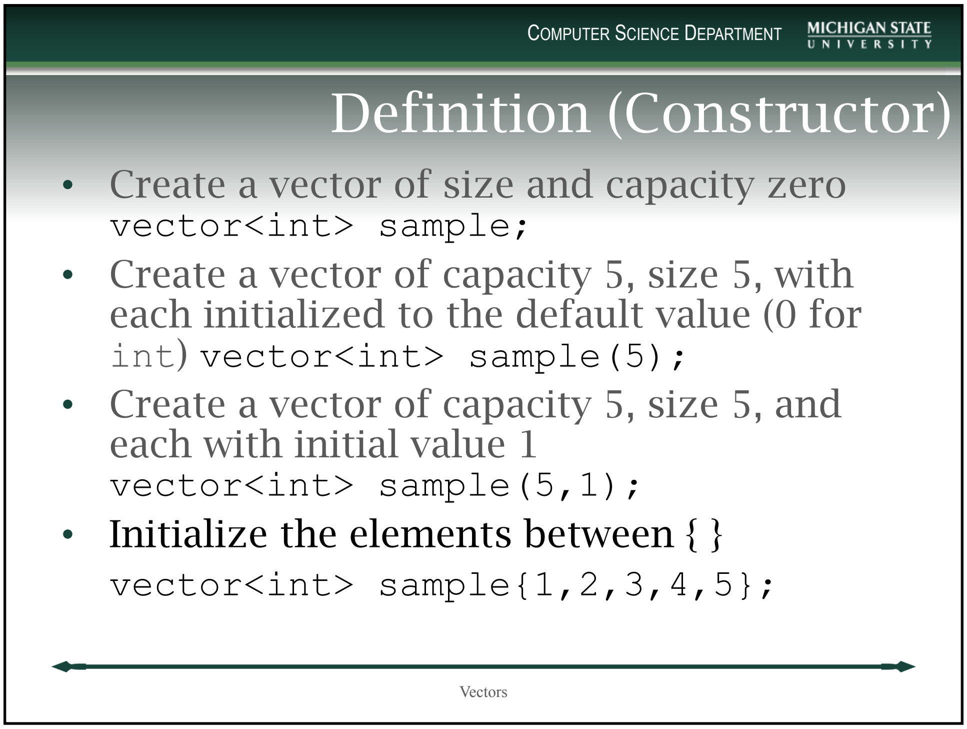
COMPUTER SCIENCE DEPARTMENT MICHIGAN STATE UNIVERSITY

size vs. capacity

Because each container manages their own memory, they can grow under demand. Methods that reflect this:

- `size`: how much the container presently holds.
- `capacity`: how much it could hold before it has to grow and manage memory.

Vectors

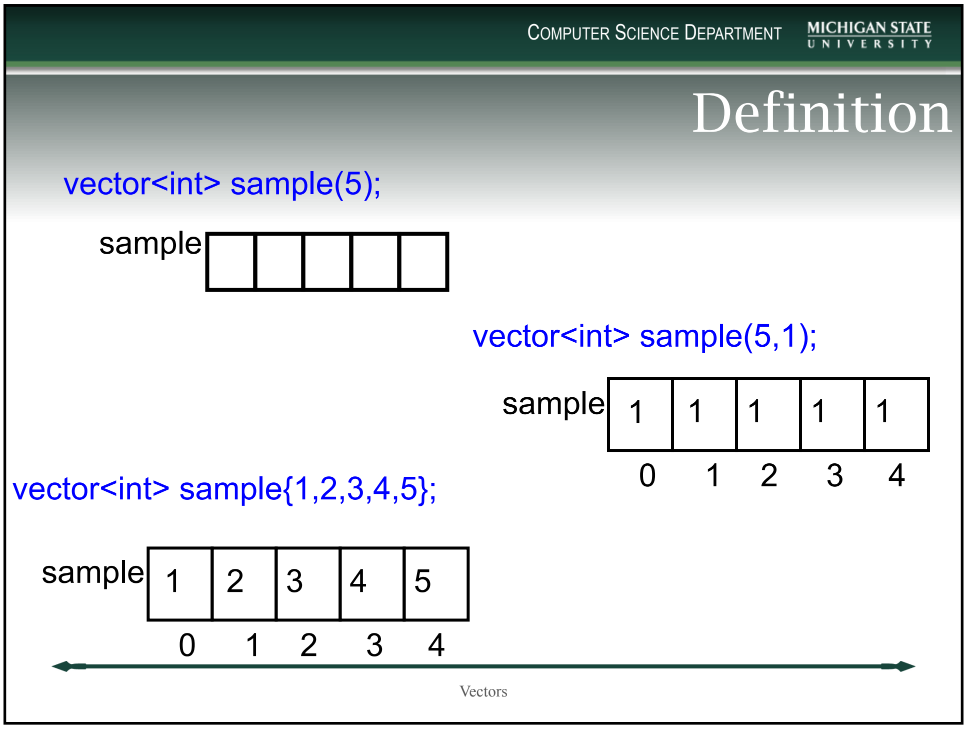


COMPUTER SCIENCE DEPARTMENT MICHIGAN STATE UNIVERSITY

Definition (Constructor)

- Create a vector of size and capacity zero `vector<int> sample;`
- Create a vector of capacity 5, size 5, with each initialized to the default value (0 for `int`) `vector<int> sample(5);`
- Create a vector of capacity 5, size 5, and each with initial value 1 `vector<int> sample(5,1);`
- Initialize the elements between { } `vector<int> sample{1,2,3,4,5};`

Vectors



Definition

vector<int> sample(5);

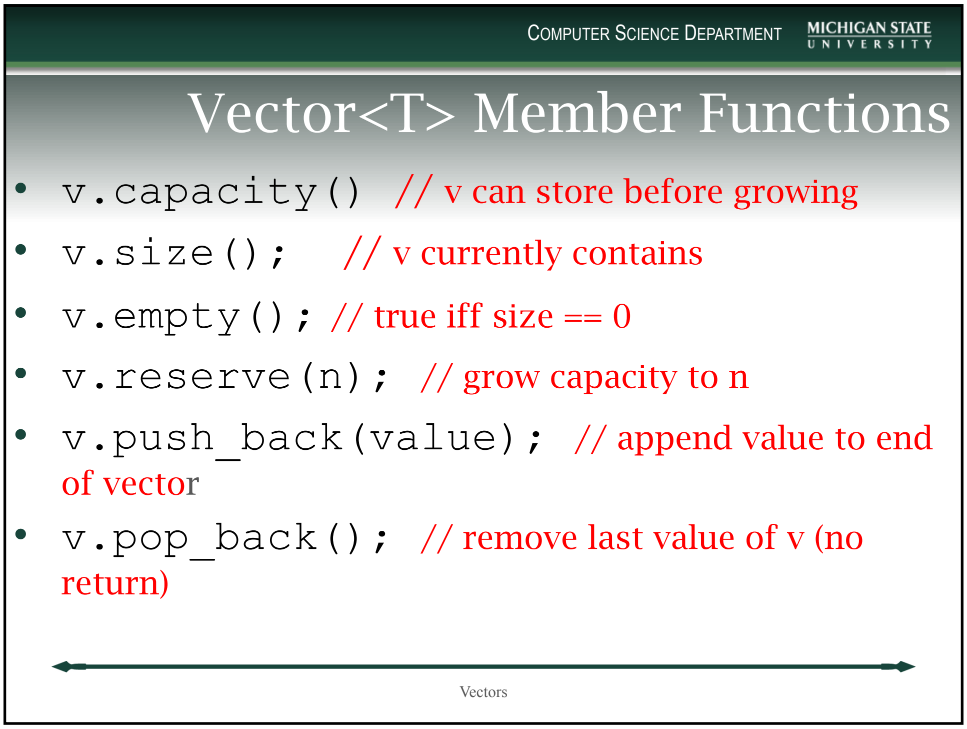
sample					

vector<int> sample(5,1);

sample	1	1	1	1	1
	0	1	2	3	4

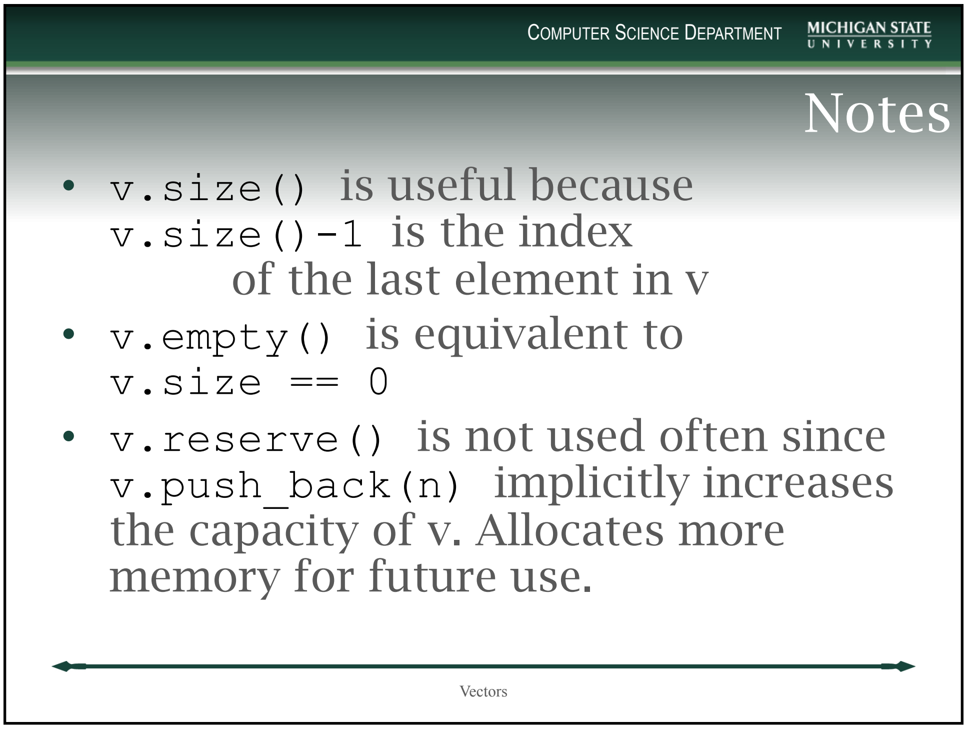
vector<int> sample{1,2,3,4,5};

sample	1	2	3	4	5
	0	1	2	3	4



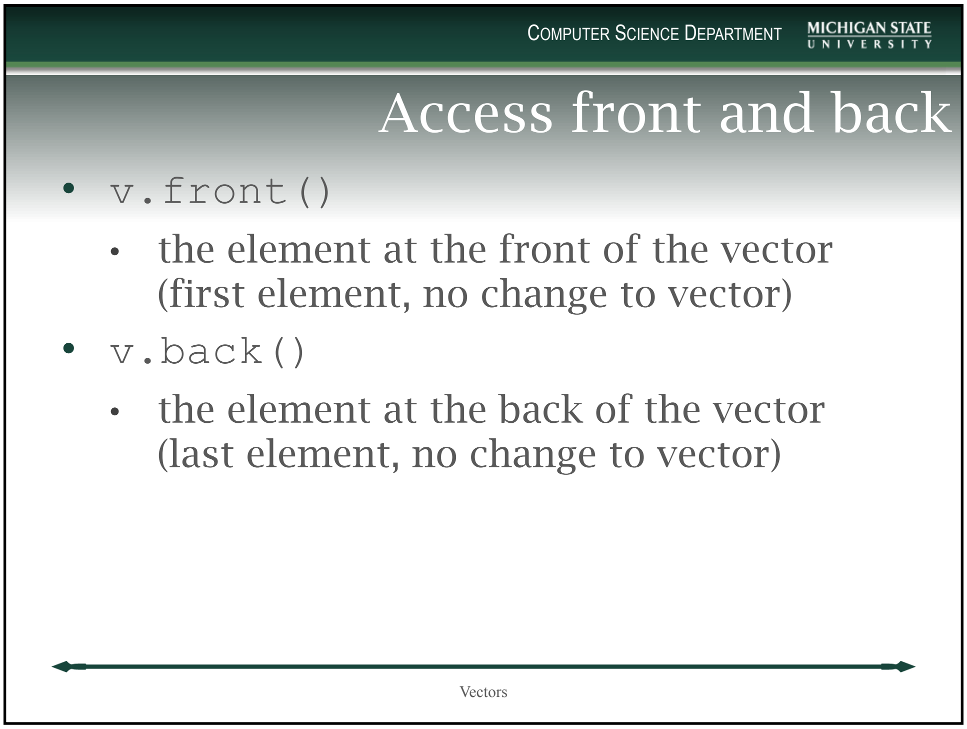
Vector<T> Member Functions

- `v.capacity()` // v can store before growing
- `v.size();` // v currently contains
- `v.empty();` // true iff size == 0
- `v.reserve(n);` // grow capacity to n
- `v.push_back(value);` // append value to end of vector
- `v.pop_back();` // remove last value of v (no return)



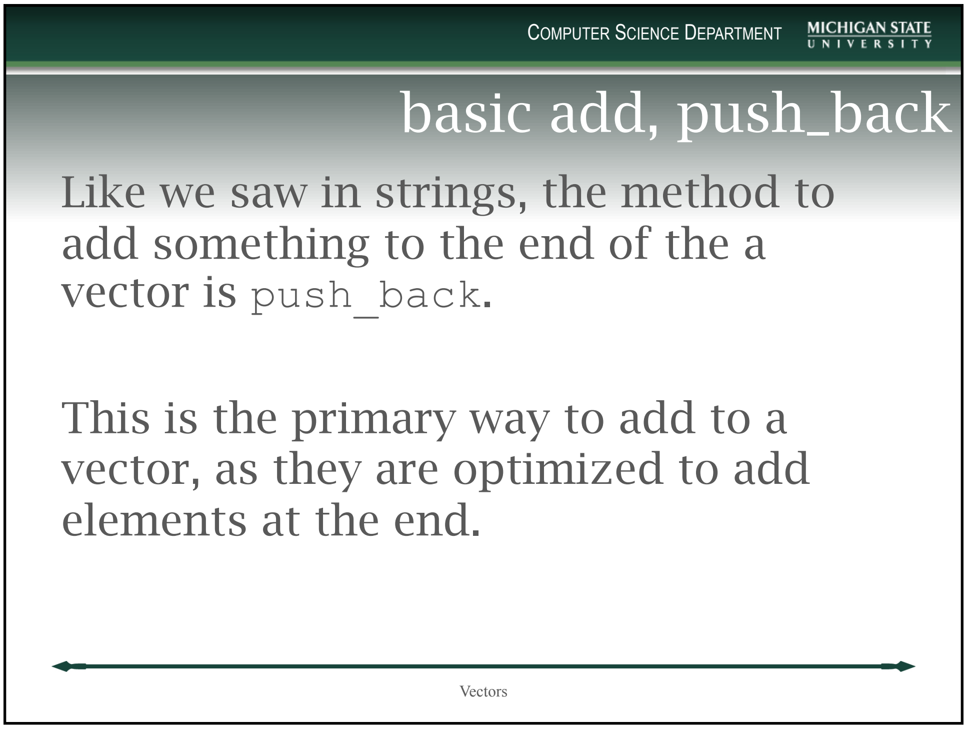
Notes

- `v.size()` is useful because `v.size()-1` is the index of the last element in v
- `v.empty()` is equivalent to `v.size == 0`
- `v.reserve()` is not used often since `v.push_back(n)` implicitly increases the capacity of v. Allocates more memory for future use.



Access front and back

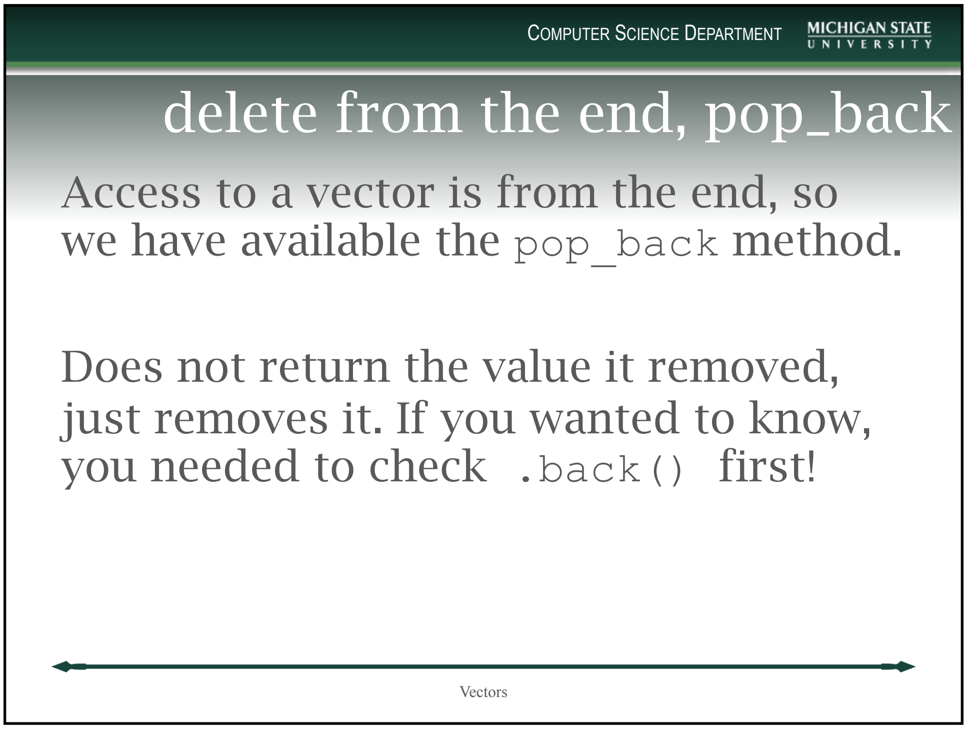
- `v.front()`
  - the element at the front of the vector (first element, no change to vector)
- `v.back()`
  - the element at the back of the vector (last element, no change to vector)



basic add, push_back

Like we saw in strings, the method to add something to the end of the a vector is `push_back`.

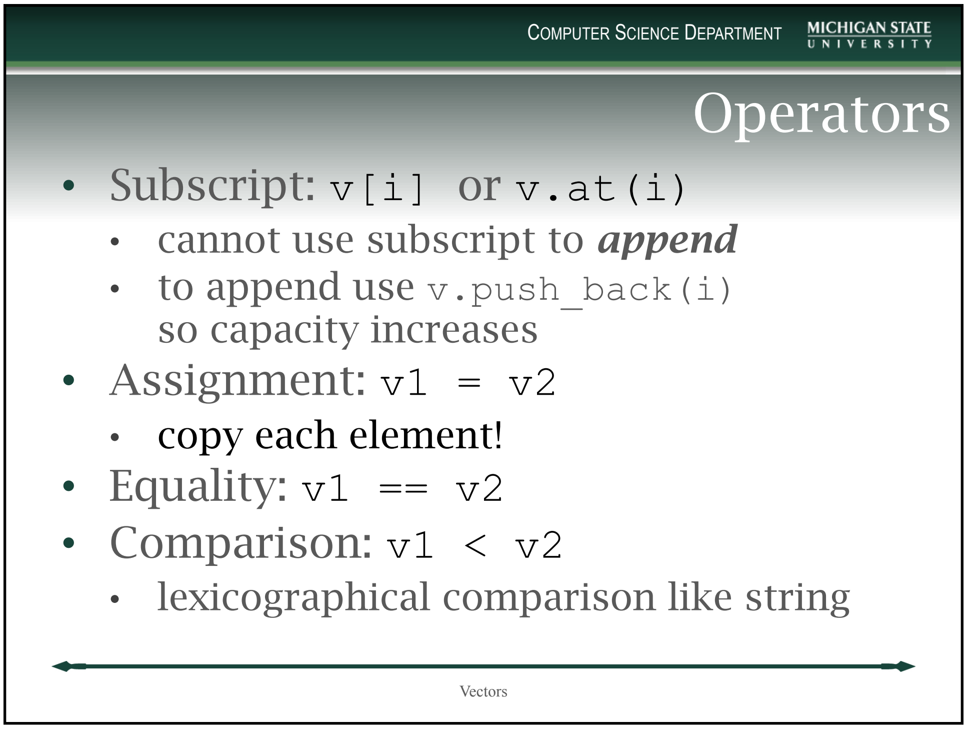
This is the primary way to add to a vector, as they are optimized to add elements at the end.



delete from the end, pop_back

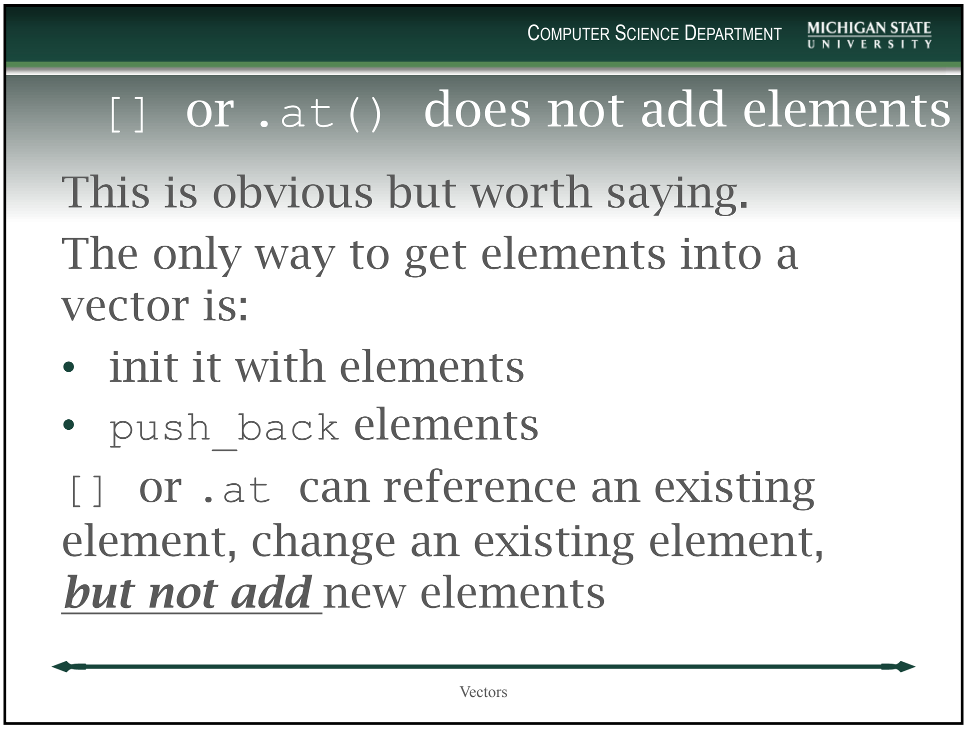
Access to a vector is from the end, so we have available the `pop_back` method.

Does not return the value it removed, just removes it. If you wanted to know, you needed to check `.back()` first!



Operators

- Subscript: `v[i]` or `v.at(i)`
  - cannot use subscript to ***append***
  - to append use `v.push_back(i)` so capacity increases
- Assignment: `v1 = v2`
  - copy each element!
- Equality: `v1 == v2`
- Comparison: `v1 < v2`
  - lexicographical comparison like string



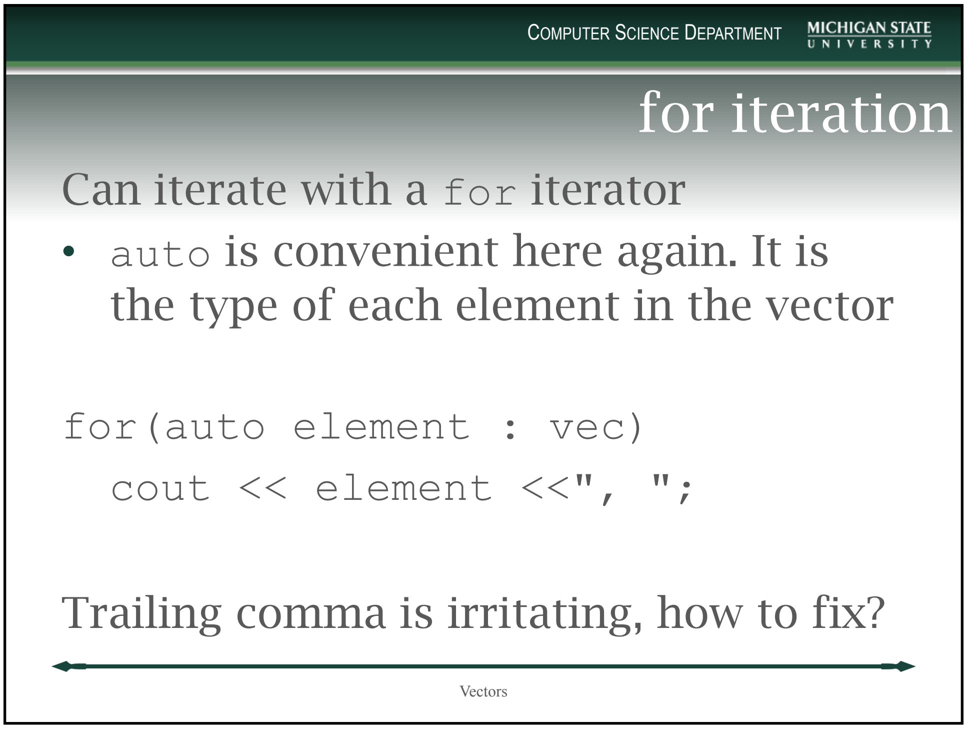
`[]` or `.at()` does not add elements

This is obvious but worth saying.

The only way to get elements into a vector is:

- init it with elements
- `push_back` elements

`[]` or `.at` can reference an existing element, change an existing element, ***but not add*** new elements



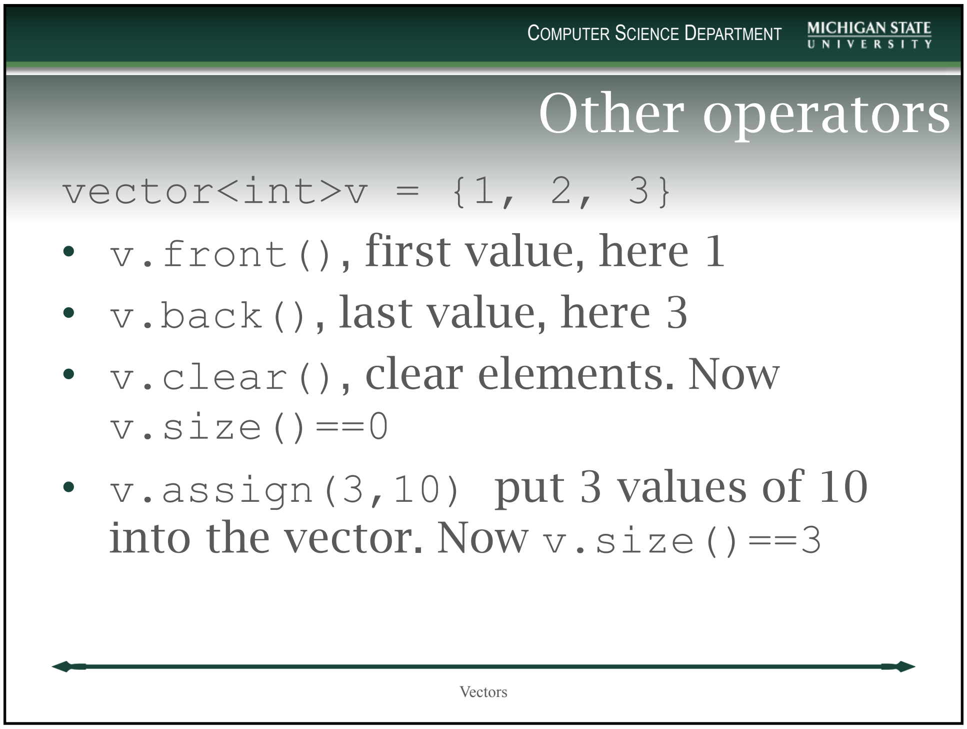
for iteration

Can iterate with a `for` iterator

- `auto` is convenient here again. It is the type of each element in the vector

```
for(auto element : vec)
  cout << element <<", ";
```

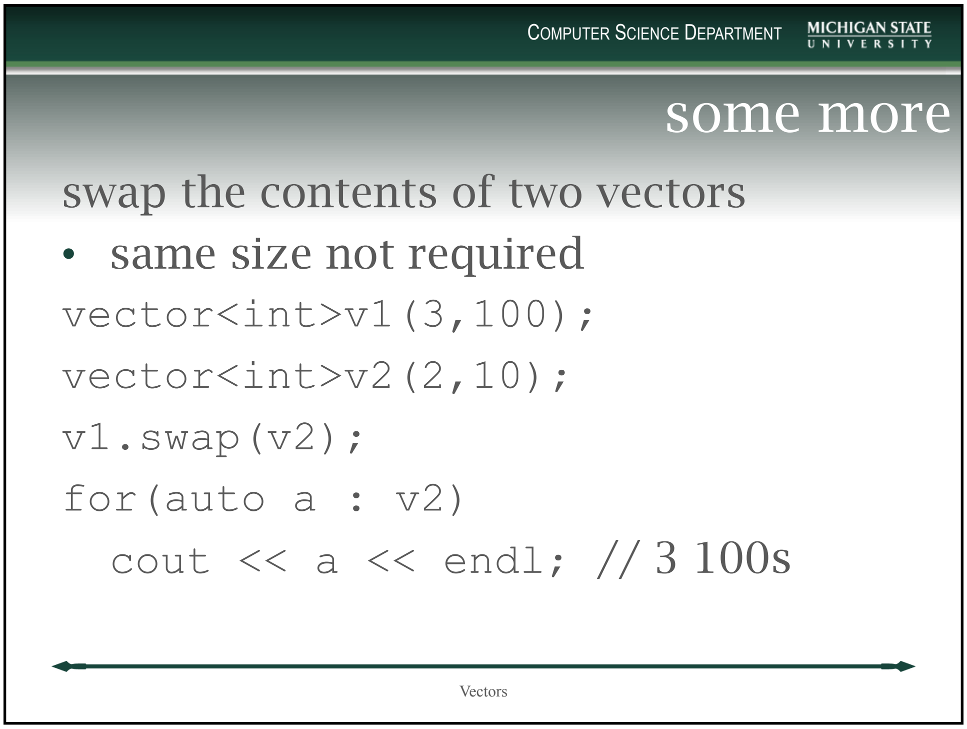
Trailing comma is irritating, how to fix?



Other operators

`vector<int>v = {1, 2, 3}`

- `v.front()`, first value, here 1
- `v.back()`, last value, here 3
- `v.clear()`, clear elements. Now `v.size()==0`
- `v.assign(3,10)` put 3 values of 10 into the vector. Now `v.size()==3`

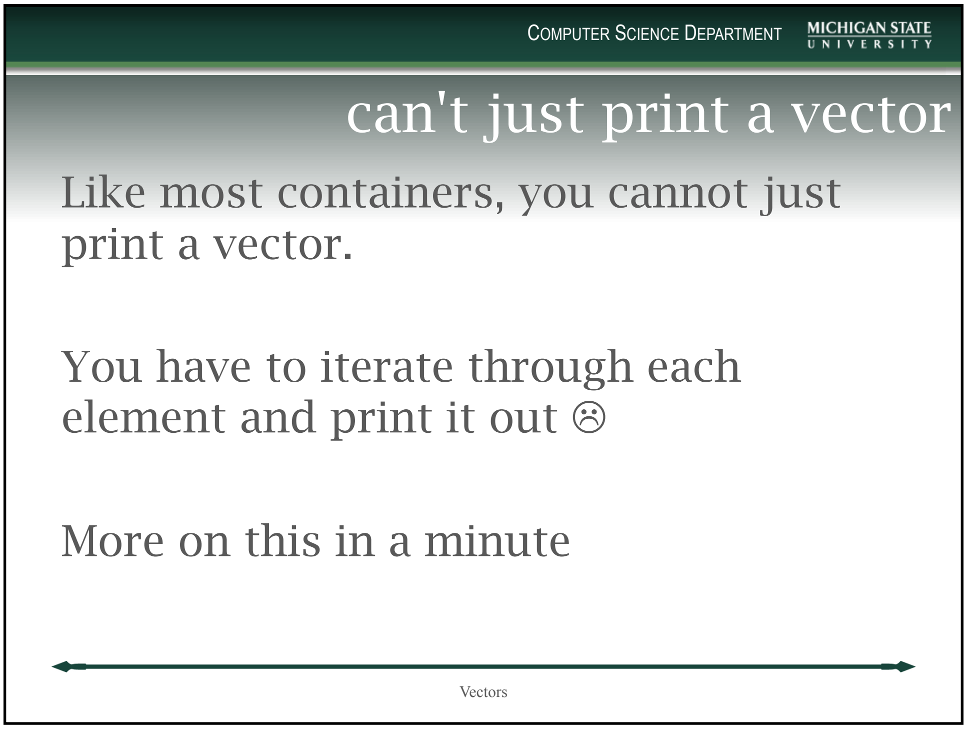


some more

swap the contents of two vectors

- same size not required

```
vector<int>v1(3,100);
vector<int>v2(2,10);
v1.swap(v2);
for(auto a : v2)
  cout << a << endl; // 3 100s
```

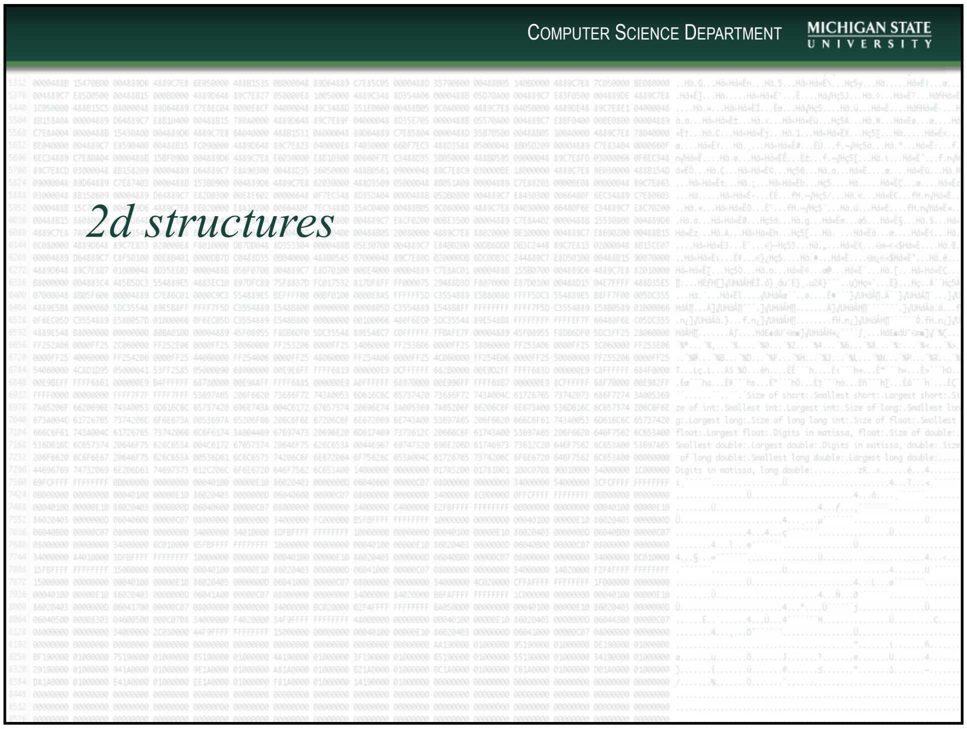


can't just print a vector

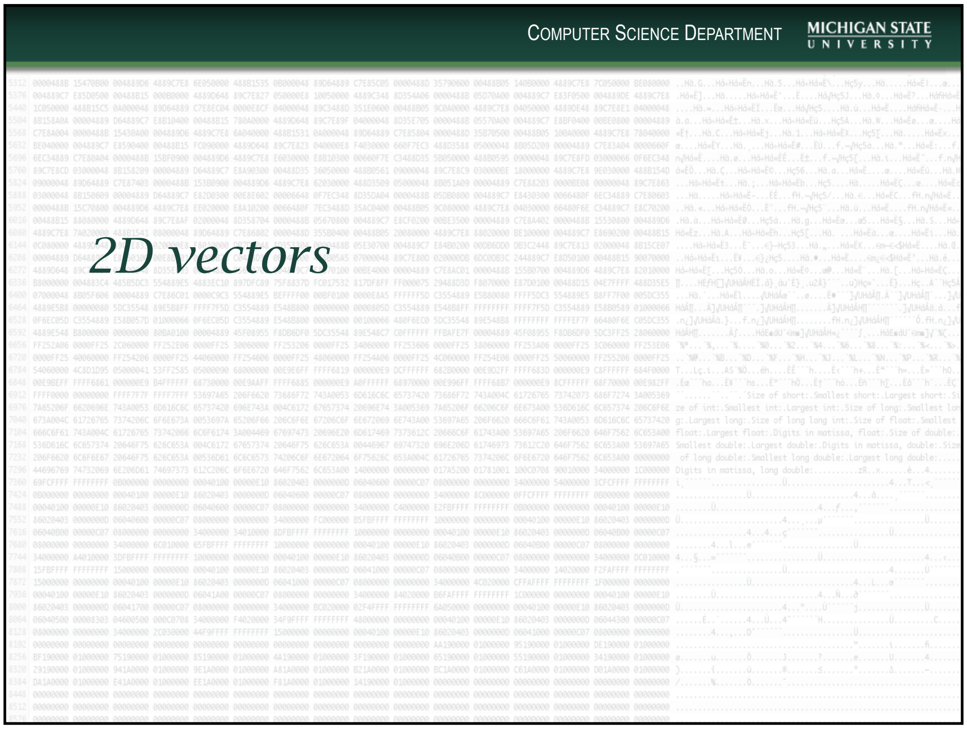
Like most containers, you cannot just print a vector.

You have to iterate through each element and print it out ☹

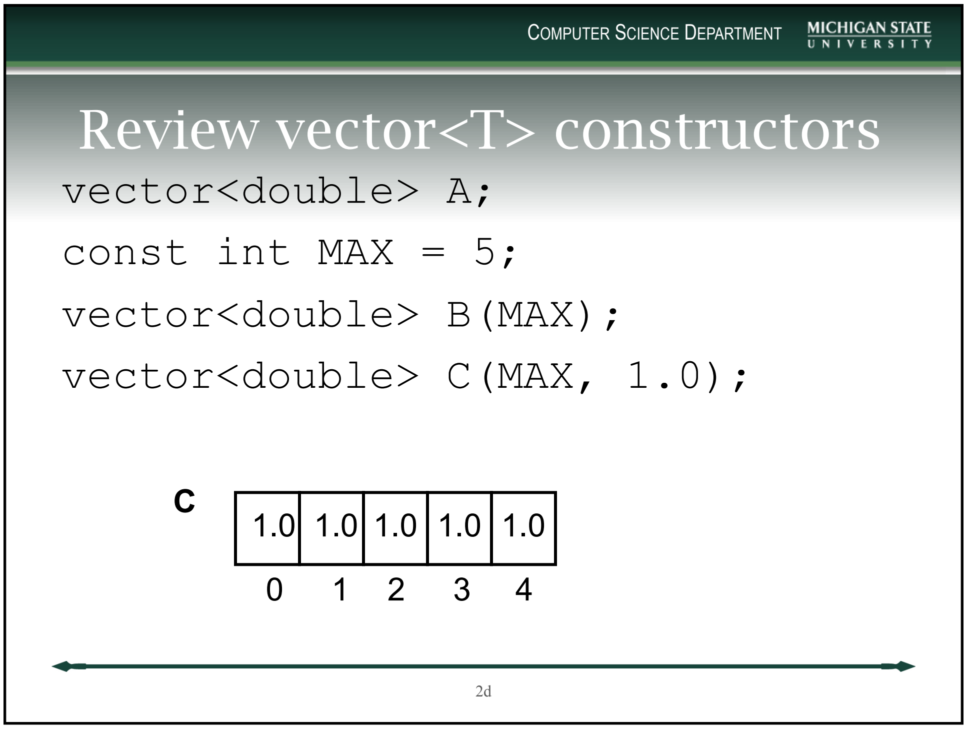
More on this in a minute



2d structures



2D vectors



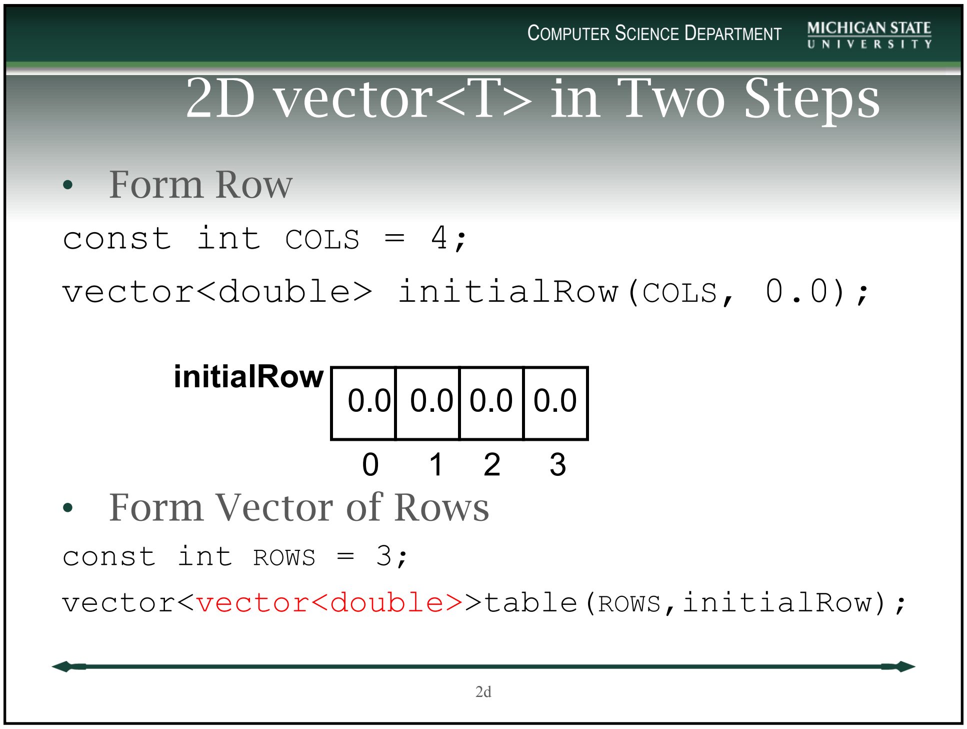
COMPUTER SCIENCE DEPARTMENT MICHIGAN STATE UNIVERSITY

Review vector<T> constructors

```
vector<double> A;
const int MAX = 5;
vector<double> B(MAX);
vector<double> C(MAX, 1.0);
```

C	1.0	1.0	1.0	1.0	1.0
	0	1	2	3	4

2d



COMPUTER SCIENCE DEPARTMENT MICHIGAN STATE UNIVERSITY

2D vector<T> in Two Steps

- Form Row

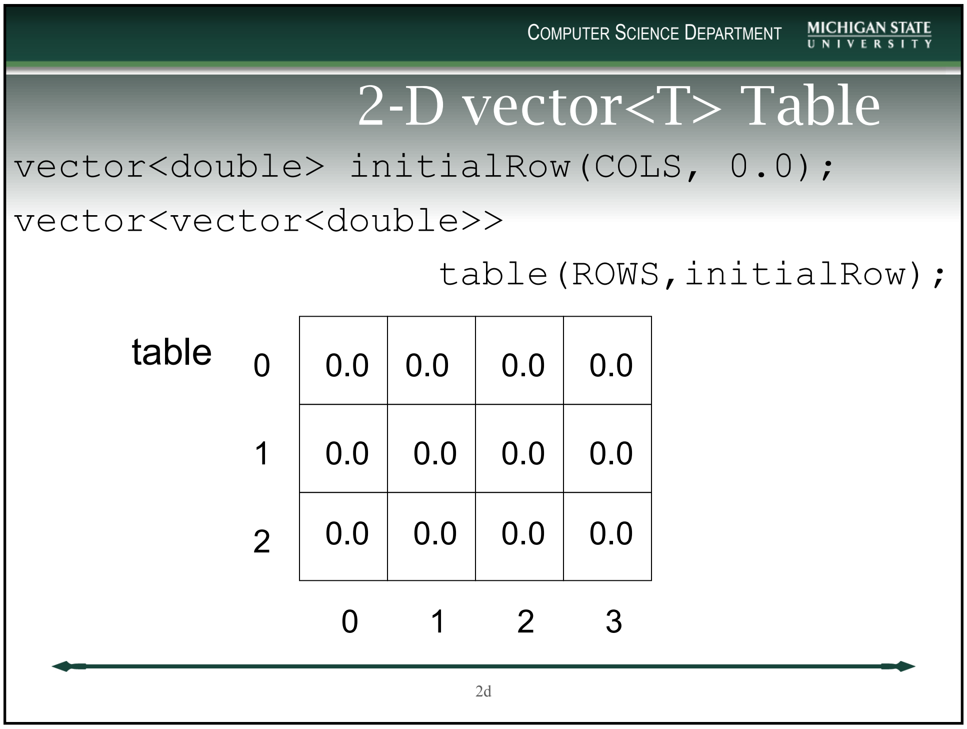
```
const int COLS = 4;
vector<double> initialRow(COLS, 0.0);
```

initialRow	0.0	0.0	0.0	0.0
	0	1	2	3

- Form Vector of Rows

```
const int ROWS = 3;
vector<vector<double>>table(ROWS,initialRow);
```

2d

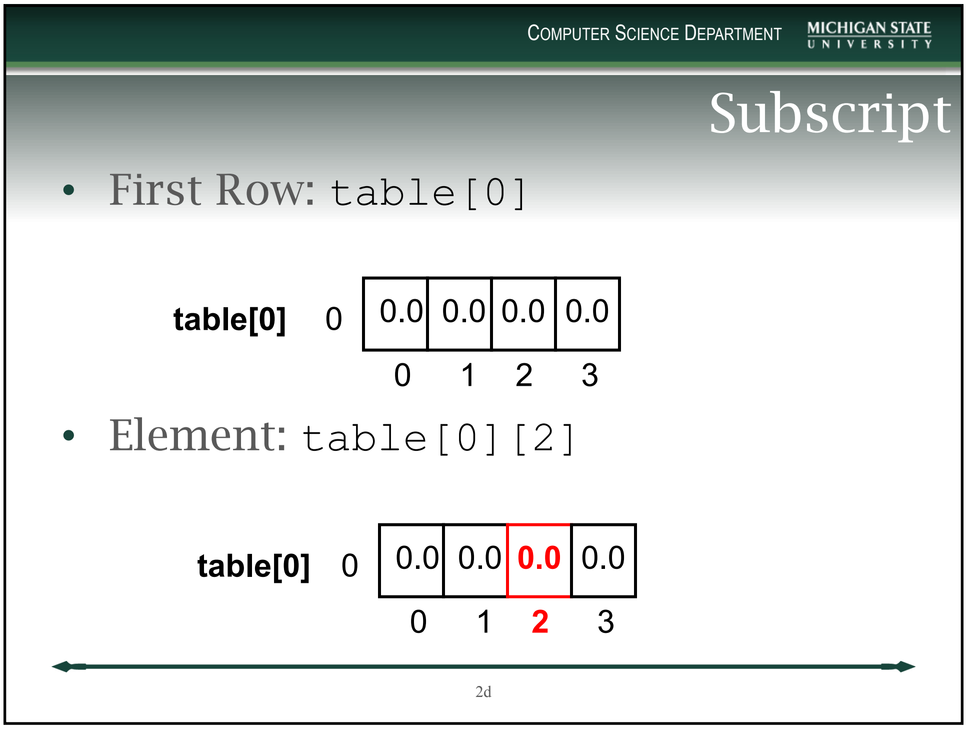


2-D vector<T> Table

```
vector<double> initialRow(COLS, 0.0);
vector<vector<double>>
                       table(ROWS,initialRow);
```

table

0	0.0	0.0	0.0	0.0
1	0.0	0.0	0.0	0.0
2	0.0	0.0	0.0	0.0
	0	1	2	3



Subscript

- First Row: `table[0]`

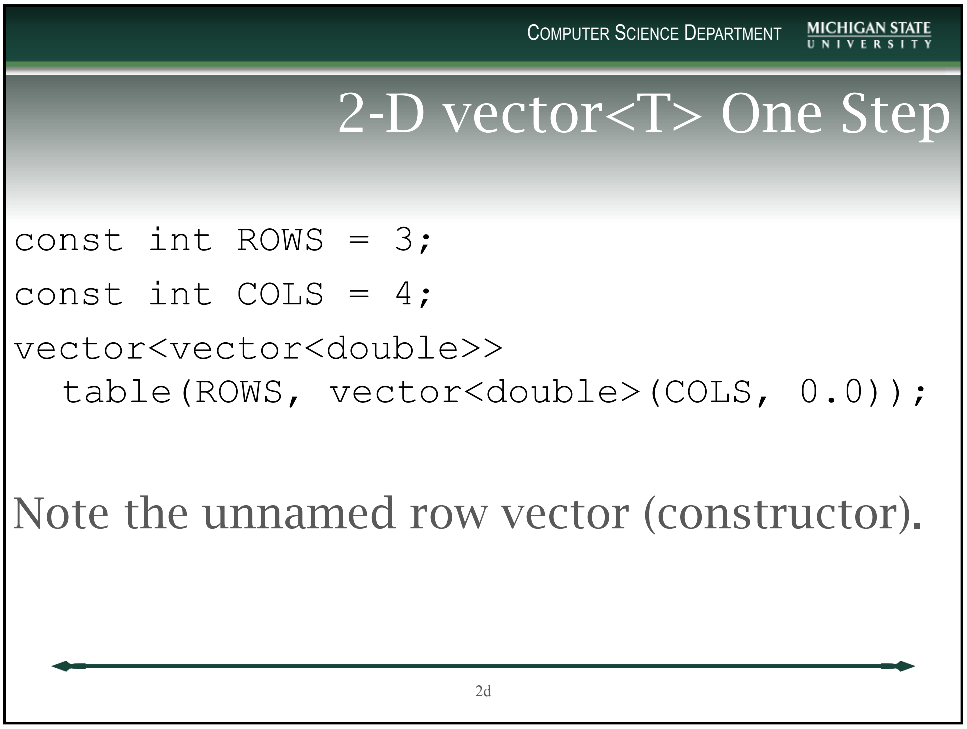
table[0]

0	0.0	0.0	0.0	0.0
	0	1	2	3

- Element: `table[0][2]`

table[0]

0	0.0	0.0	**0.0**	0.0
	0	1	**2**	3



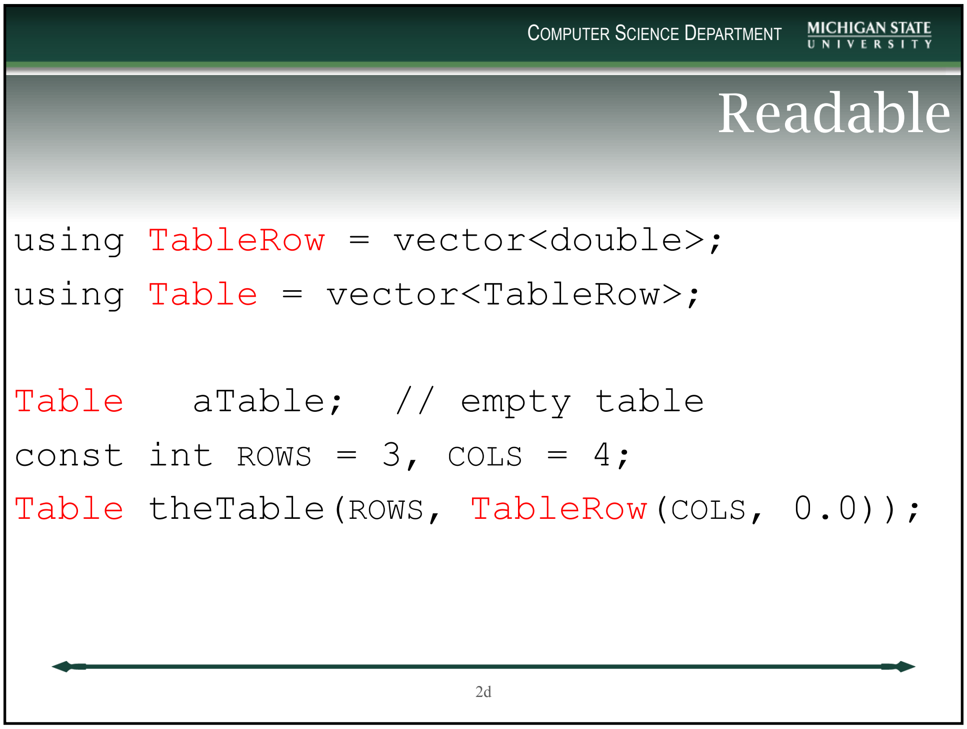
COMPUTER SCIENCE DEPARTMENT MICHIGAN STATE UNIVERSITY

2-D vector<T> One Step

```
const int ROWS = 3;
const int COLS = 4;
vector<vector<double>>
  table(ROWS, vector<double>(COLS, 0.0));
```

Note the unnamed row vector (constructor).

2d

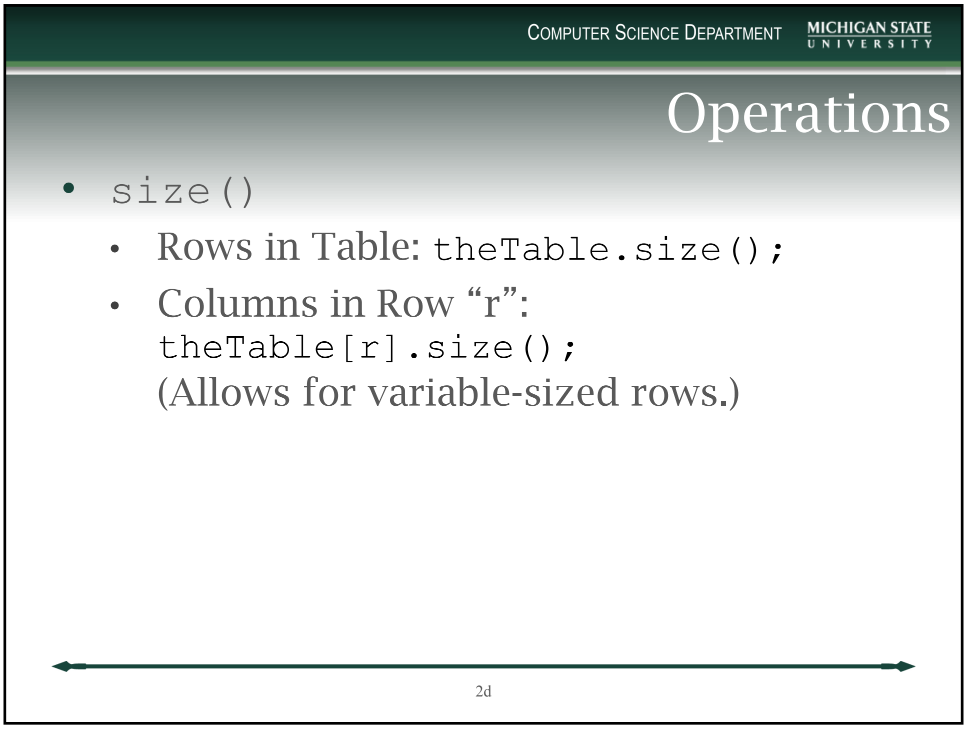


COMPUTER SCIENCE DEPARTMENT MICHIGAN STATE UNIVERSITY

Readable

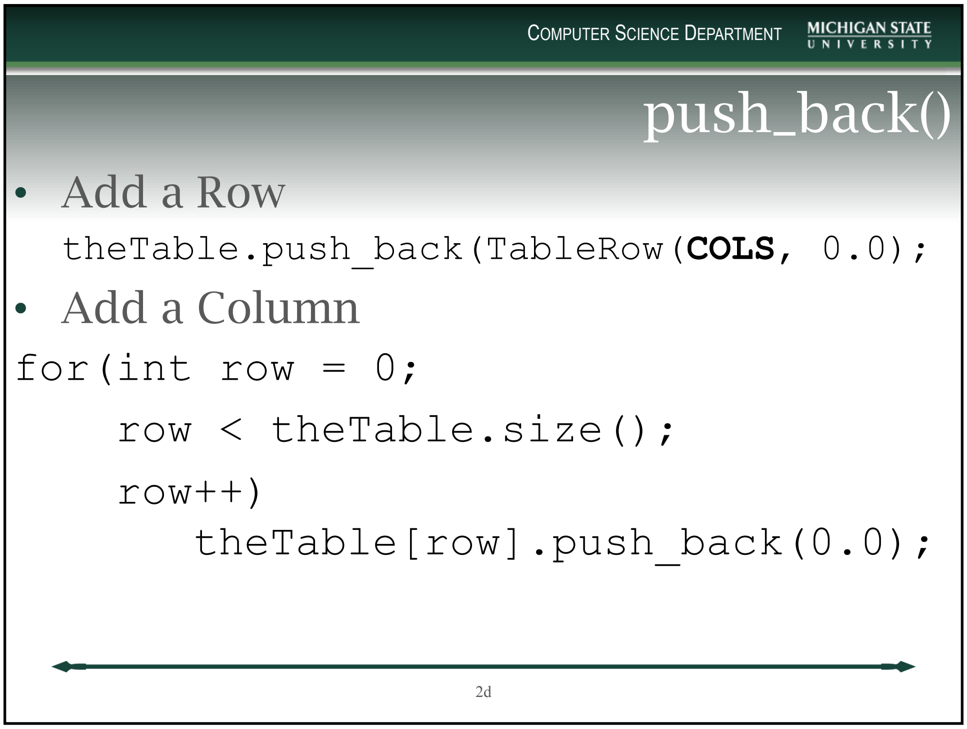
```
using TableRow = vector<double>;
using Table = vector<TableRow>;

Table   aTable;  // empty table
const int ROWS = 3, COLS = 4;
Table theTable(ROWS, TableRow(COLS, 0.0));
```

2d



Operations

- `size()`
  - Rows in Table: `theTable.size();`
  - Columns in Row “r”: `theTable[r].size();` (Allows for variable-sized rows.)



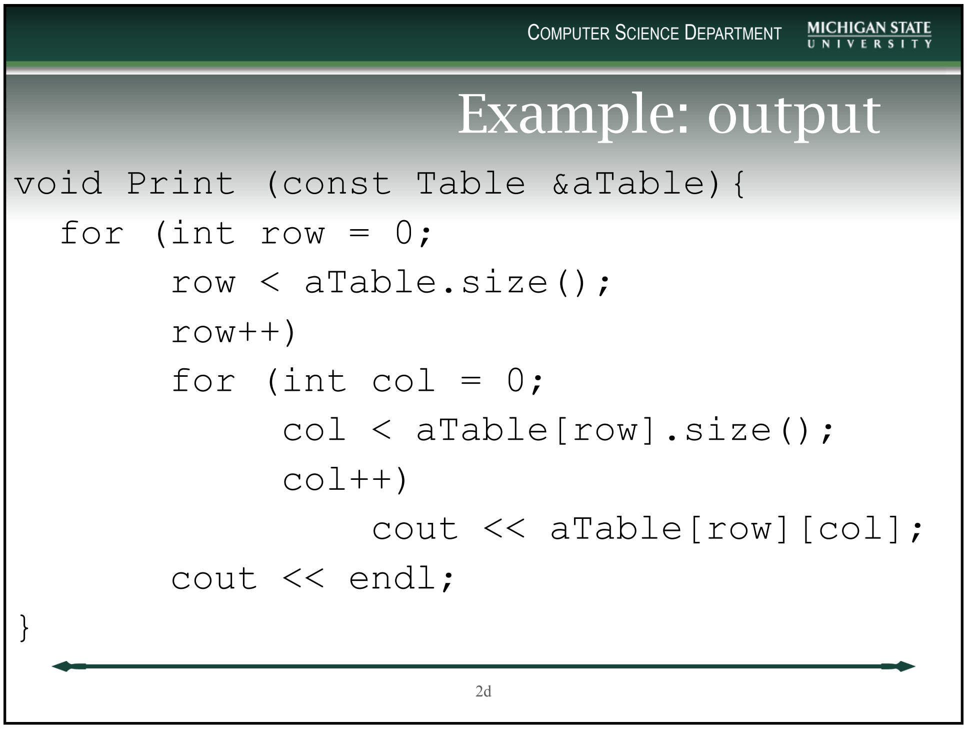
push_back()

- Add a Row

```
theTable.push_back(TableRow(COLS, 0.0);
```

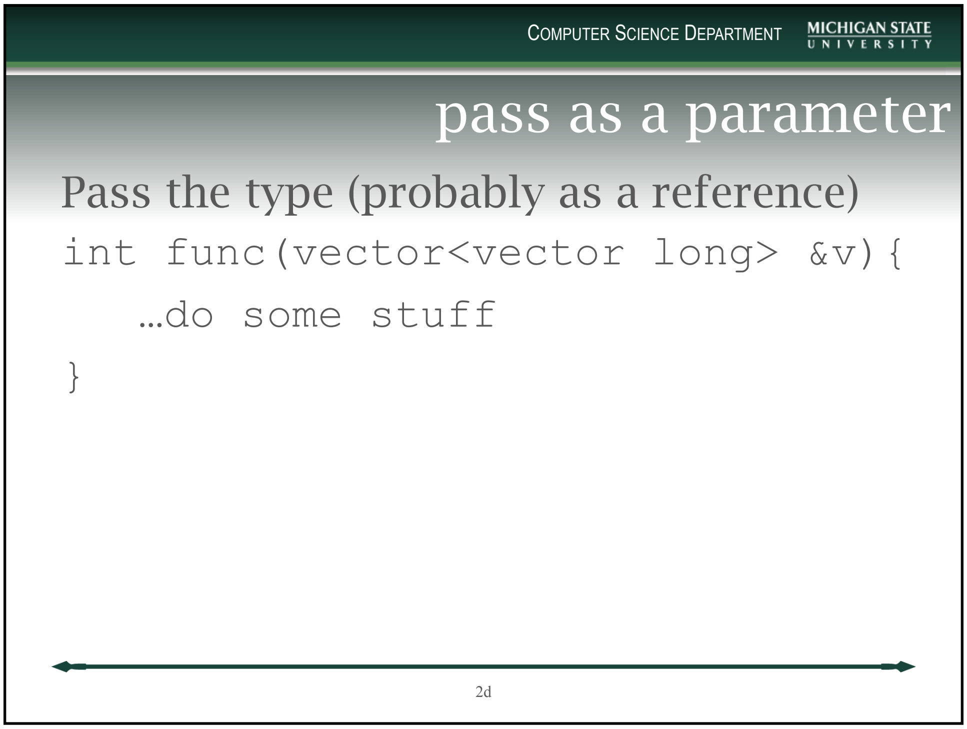
- Add a Column

```
for(int row = 0;
    row < theTable.size();
    row++)
       theTable[row].push_back(0.0);
```



Example: output

```
void Print (const Table &aTable){
  for (int row = 0;
       row < aTable.size();
       row++)
       for (int col = 0;
            col < aTable[row].size();
            col++)
                cout << aTable[row][col];
       cout << endl;
}
```



pass as a parameter

Pass the type (probably as a reference)

```
int func(vector<vector long> &v){
   …do some stuff
}
```