Dynamic memory management using Pointers

CS 115

Dr. Joseph Eremondi, adapted from Dr. Shakil Khan, Dr. Philip Fong, and Dr. Howard Hamilton

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Pointers and New

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- Solution: allocate memory on demand at run-time!

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cout << *px;
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```
...
delete px;
px = nullptr;
```

Simple example: Book Record

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```cpp
struct Book {
  string title;
  string author;
  string call_number;
};
void printBook(const Book *pBook){
  cout << "title: " << pBook->title << endl;
  cout << "author: " << pBook->author << endl;
  cout << "call number: " << pBook->call_number;
  cout << endl;
}
int main(){
  // allocate a Book from heap
  Book *pb = new Book;
  pb->title = "Security";
  pb->author = "Matt Bishop";
  pb->call_number = "QA.420";
  printBook(pb);
  delete pb; // explicit deallocation
  return 0;}
```

Pictorial representation: Run-time Allocation

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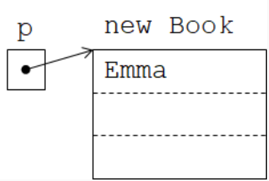
```
Book *p;
p = new Book;
p -> title = "Emma";
```



Safely Allocating Memory

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```
Book *pb[10];

for (int i = 0; i < 10; I++){
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```

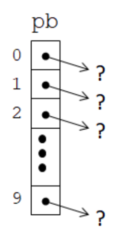

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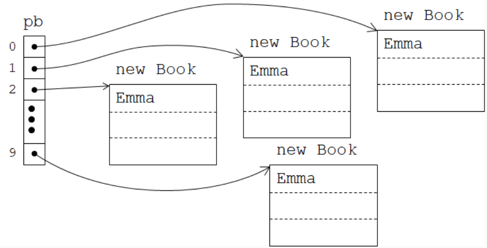

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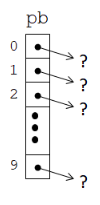

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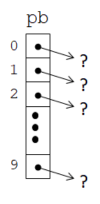

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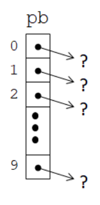

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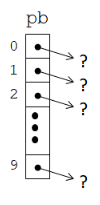

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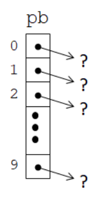

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  - This is *good!*
  - Crashes right at the point of failure
  - Doesn’t silently fail and access garbage memory

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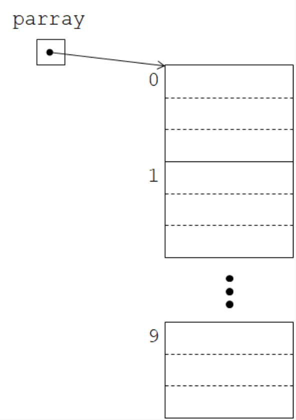

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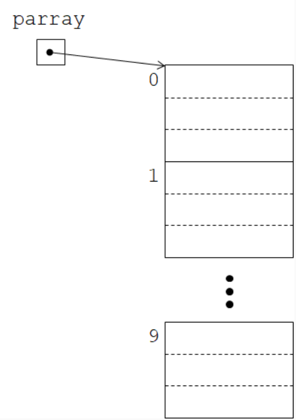

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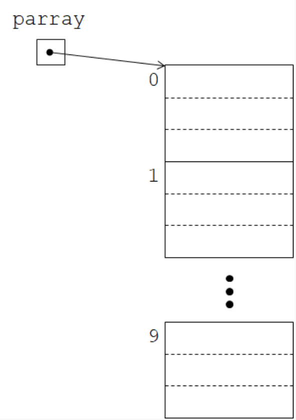
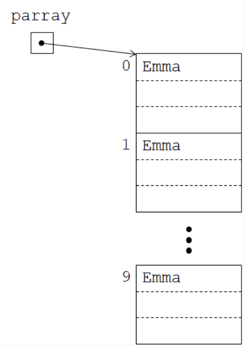


```
for (int i = 0; i < 10; i++)
  parray[i].title = "Emma";

// could have also used:
// (parray+i)->title = "Emma";
// (*(parray+i)).title = "Emma";
```



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delete [ ] parray;

parray = nullptr;
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  - Get the value `i` places after the start of the array
- Why we always need to pass the length of the array
  - Address tells us where it starts, not where it ends

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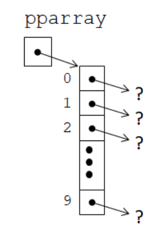

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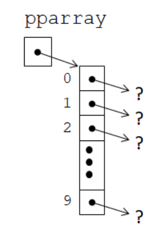

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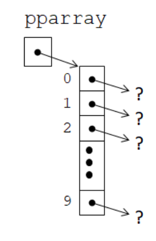

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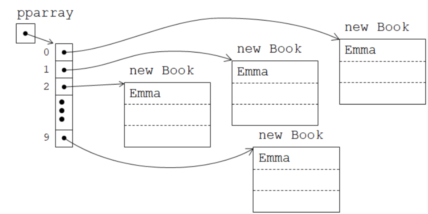

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```
for (int i = 0; i < 10; i++){
  delete pparray[i];
  // following is redundant, since we
  // are about to delete parray
  pparray[i] = nullptr;
 }
delete [] pparray;
pparray = nullptr;
```

Collection data structures with maximum capacity

- Example: print in reverse order

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```
const int CAPACITY = 1000;

int main(){
  int A[CAPACITY];
  int length;

  cin >> length;

  for (int i = 0; i < length; i++)
    cin >> A[i];


  for (int i = length - 1; i >= 0; i--)
    cout << A[i] << endl;

  return 0;
}
```

Collection data structures w/o maximum capacity

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```
int main(){
  int length;
  int *A;

  // Read length of sequence
  cin >> length;

  // Allocate enough memory to hold
  // sequence
  A = new int[length];

  for (int i = 0; i < length; i++)
    cin >> A[i];

  // Write sequence in rev. order
  for (int i = length - 1; i >= 0; i--)
    cout << A[i] << endl;

  // Deallocate memory
  delete [] A;
```

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- copy the contents of the old array to the new one
- deallocate the old array
- use the new array to store incoming integers until it is filled up again
- Deallocate the array when it is no longer needed

Expand/Shrink main function

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```cpp
int main(){
  // Initialize encapsulated array
  init();

  // Read sequence
  int x;
  cin >> x;
  while (cin){
    append(x);
    cin >> x;
  }

  // Write sequence in reverse order
  for (unsigned int i = length(); i > 0; i--)
    cout << retrieve(i - 1) << endl;

  // Deallocate encapsulated array
  cleanup();

  return 0;
}
```

Initializing

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```
// Amount of memory available
unsigned int array_capacity = 0;
// Amount of memory used
unsigned int array_length = 0;
// Actual memory resource
int *array = nullptr;

bool isInitialized(){
  return (array != nullptr);
}

void init(){
  assert(! isInitialized());
  // Default initial capacity
  array_capacity = 4;
  // Array is empty initially
  array_length = 0;
  // Allocate array
  array = new int[array_capacity];
  assert(isInitialized());
} // end init()
```

Example: Append for shrinking/growing

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```
void append(int x) {
  assert(isInitialized());

  // Expand capacity if full
  if (array_length == array_capacity)
    expand();

  // Append to the end
  array[array_length] = x;
  // Update array length
  array_length++;
}
```

Expand for Shrinking/Growing

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```
void expand() {
  assert(isInitialized());
  assert(array_capacity > 0);
  assert(array_length == array_capacity);

  // Calculate new capacity
  int new_array_capacity = array_capacity * 2;
  // Allocate bigger array
  int *new_array = new int[new_array_capacity];

  // Copy contents
  for (unsigned int i = 0; i < array_length; i++)
    new_array[i] = array[i];
  // Deallocate old array
  delete[] array;

  // Use new array and update capacity
  array = new_array;
  array_capacity = new_array_capacity;
  assert(array_length < array_capacity);
}
```

Shrinking/Growing: Retrieve and Cleanup

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```
unsigned int length(){
  assert(isInitialized());
  return array_length;
}

int retrieve(unsigned int i){
  assert(isInitialized());
  assert(i < length());
  return array[i];
}

void cleanup(){
  assert(isInitialized());
  // Deallocate memory resource
  delete [] array;
  // Establish postconditions
  array = nullptr;
  array_capacity = 0;
  array_length = 0;
  assert(! isInitialized());
}
```

Dynamically allocated 2d arrays

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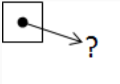
```
// allocate the 2D array
int** pparray;
```



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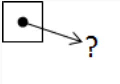

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pparray = nullptr;
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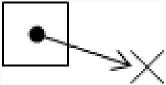

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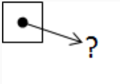

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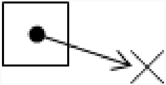

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pparray = new int*[10];
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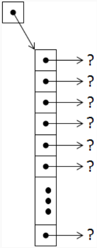
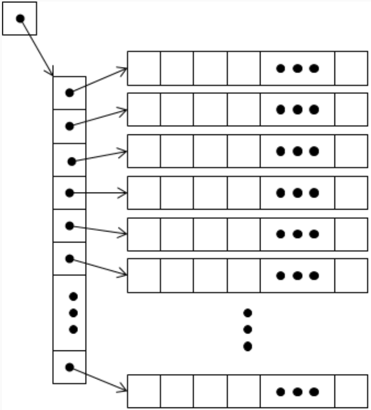


Allocating the Second Dimension

Allocating the Second Dimension

```
// allocate the 2D array
int** pparray = nullptr;
pparray = new int*[10];

for (unsigned int i = 0; i < 10; i++){
  pparray[i] = new int[20];
 }
```



Using Dynamic 2D arrays

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```
// store 7 in position 6 of row 2
pparray[2][6] = 7;
```

- How about using pointers?

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- How about using pointers?

```
 *(*(parray + 2) + 6) = 7;
// when done:
// deallocate in reverse order
for (unsigned int i = 0; i < 10; i++)
  delete [] pparray[i];
delete [] pparray;
```