SORTING AND SEARCHING

Java

Sorts and Searches

List

frequently used methods

Name	Use
indexOf(x)	returns -1 if not found returns loc in list if found
contains(x)	returns true if x exists in list returns false if x does not exist in list
equals(x)	returns true if this list is equal to x

```
import  java.util.List;
```

List Searches

```
ArrayList<Integer> ray;
ray=new ArrayList<Integer>();
ray.add(21);
ray.add(14);
ray.add(0,13);
ray.add(25);
out.println( ray.indexOf( 21 ) );
out.println( ray.indexOf( 17 ) );
out.println( ray.contains(25 ) );
out.println( ray.contains( 63 ) );
```

OUTPU0

1

-1

true

false

Arrays

frequently used methods

Name	Use
sort(x)	puts all items in x in ascending order
binarySearch(x,y)	checks x for the location of y
equals(x,y)	checks if x and y have the same values
fill(x, y)	fills all spots in x with value y

```
import  java.util.Arrays;
```

Java Searches

```
String s  = "abcdefghijklmnop";
out.println(s.indexOf("3"));


int[] ray = {3,4,5,6,11,18,91};
out.println(Arrays.binarySearch(ray,5));


int[] ray = {3,4,5,6,11,18,91};
out.println(Arrays.binarySearch(ray,15));
```

OUTPUT

-1
2
-6

Java Sorts

```
int[] ray = {13,6,17,18,2,-5};
Arrays.sort(ray);

for(int i = 0; i < ray.length; i++)
{
    out.println(ray[i]);
}
```

OUTPUT-

```
5
2
6
13
17
18
```

Collections

frequently used methods

Name	Use
sort(x)	puts all items in x in ascending order
binarySearch(x,y)	checks x for the location of y
fill(x,y)	fills all spots in x with value y
rotate(x)	shifts items in x left or right
reverse(x)	reverses the order of the items in x

```
import  java.util.Collections;
```

Java Sorts

```
ArrayList<Integer> ray;
ray=new ArrayList<Integer>();
ray.add(21);
ray.add(2);
ray.add(13);
ray.add(-1);
ray.add(3);
Collections.sort(ray);

for(int  num  :  ray )
   out.println(num);
```

OUTPUT-

1
2
3
13
21

Searching

Linear / Sequential Search

The Linear Search searches through a list one element at time looking for a match. The index position of a match is returned if found or -1 is returned if no match is found.

Linear with Primitives

```
int linearSearch(int[] stuff, int val)
{
   for(int i=0; i< stuff.length; i++)
   {
      if (stuff[i] == val )
         return i;
   }
   return -1;   //returns -1 if not found
}
```

Linear with Objects

```
int linearSearch(Comparable[] stuff,
                                    Comparable item)
{
    for(int i=0; i<stuff.length; i++)
    {
        if (stuff[i].compareTo(item)==0)
                return i;
    }
    return -1;   //returns -1 if not found
}
```

1/2

Binary Search

0100100101

BinarySearch

The Binary Search works best with sorted lists. The Binary search cuts the list in half each time it checks for for the specified value. If the value is not found, the search continue in the half most likely to contain the value.

```
int binarySearch (int [] stuff, int val )
{
   int bot= 0, top = stuff.length-1;
   while(bot<=top)
   {
      int middle = (bot + top) / 2;
      if (stuff[middle] == val)  return middle;
      else
         if (stuff[middle] > val)
            top = middle-1;
         else
            bot = middle+1;
   }
   return -1;
}
```

BinarySearch

```
public static int binarySearch (int [] s, int v,
                                                    int b, int t
)
{
   if(b<=t)
   {
      int m = (b + t) / 2;
      if (s[m] == v)
          return m;
      if (s[m] > v)
            return binarySearch(s, v, b, m-1);
      return binarySearch(s, v, m+1, t);
   }
   return -1;
}
```

BinarySearch

```
int[] stuff = {1,6,8,10,14,22,30,50};
```

0 + 7 = 7 / 2 = 3
stuff[3] = 10

4 + 7 = 11 div 2 = 5
stuff[5] = 22

6 + 7 = 13 div 2 = 6
stuff[6] = 30

BinarySearch

If you are searching for 25, how many times will you check the stuff?

Binary Search ShortCut

Given a list of N items.

What is the next largest power of 2?

If N is 100, the next largest
power of 2 is 7.

$\text{Log}_2(100) = 6.64386$

$2^7 = 128$.

It would take 7 checks max to find if an item
existed in a list of 100 items.

General Big O Chart for Searches

Name	Best Case	Avg. Case	Worst Case
Linear/Sequential Search	O(1)	O(N)	O(N)
Binary Search	O(1)	O($\log_2$ N)	O($\log_2$ N)

All searches have a best case run time of O(1) if written properly. You have to look at the code to determine if the search has the ability to find the item and return immediately. If this case is present, the algorithm can have a best case of O(1).

Sorts
Quadratic (N^2)

The Bubble Sort

Bubble Sort

Bubble sort compares items that are adjacent and has to potential to swap a whole lot.

Bubble Sort is left in for historical purposes only!

Bubble Sort W/Objects

```
void bubbleSort( Comparable[] stuff ){
  for(int i=0; i<stuff.length-1; i++){
    for(int j=0; j<stuff.length-1; j++){
      if(stuff[ j].compareTo(stuff[ j+1]) > 0 ){
        Comparable temp = stuff[ j];
        stuff[ j] = stuff [ j+1];
        stuff [ j+1] = temp;
      }
    }
  }
}
```

Lots O Swaps!

The Selection Sort

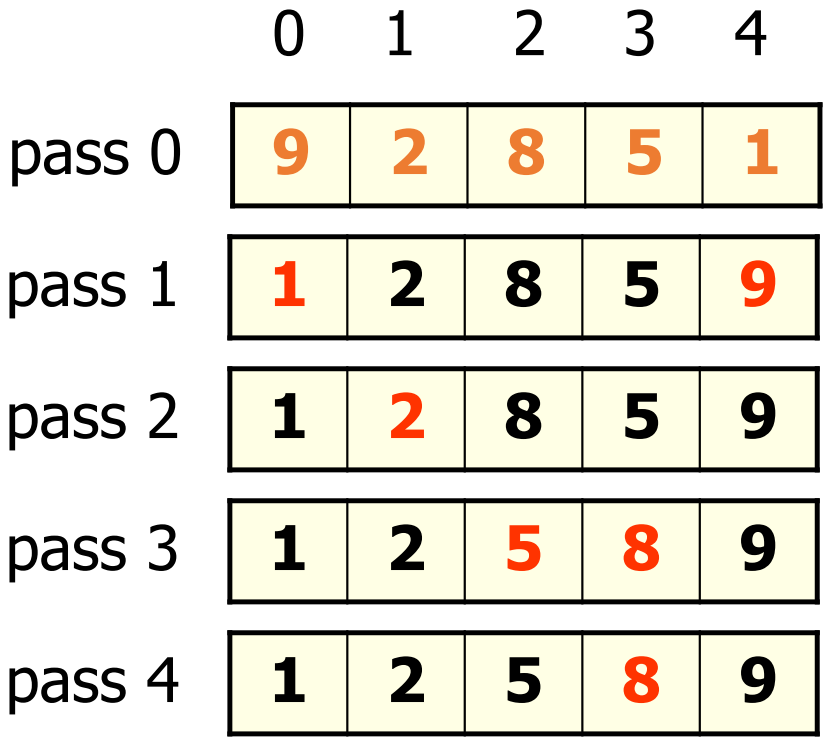
Selection Sort

The selection sort does not swap each time it finds elements out of position. Selection sort makes a complete pass while searching for the next item to swap. At the end of a pass once the item is located, one swap is made.

Selection Sort

```
void selectionSort( int[] ray  )
{
      for(int i=0; i< ray.length-1; i++){
        int min = i;
        for(int j = i+1; j< ray.length; j++)
        {
           if(ray[j] < ray[min])
              min = j;     //find location of smallest
        }
        if( min != i) {
           int temp = ray[min];
           ray[min] = ray[i];
           ray[i] = temp;          //put smallest in pos i
       }
    }
}
```

Selection Sort



```
public void selSort(Comparable[] stuff){
  for(int i=0;i<stuff.length-1;i++)
  {
    int spot=i;
    for(int j=i;j<stuff.length;j++){
      if(stuff[j].compareTo(stuff[spot])>0)
        spot=j;
    }
    if(spot==i) continue;
    Comparable save=stuff[i];
    stuff[i]=stuff[spot];
    stuff[spot]=save;
  }
}
```

How many swaps per pass?

Selection Sort W/Objects

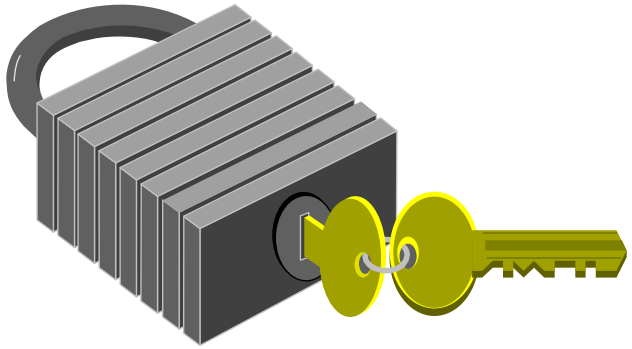
Selection Sort in Action

Original List

```
Integer[] ray = {90,40,20,30,10,67};
```

```
pass 1  -  90  40  20  30  10  67
pass 2  -  90  67  20  30  10  40
pass 3  -  90  67  40  30  10  20
pass 4  -  90  67  40  30  10  20
pass 5  -  90  67  40  30  20  10
pass 6  -  90  67  40  30  20  10
```

The Insertion Sort



Insertion Sort

The insertion sort first selects an item and moves items up or down based on the comparison to the selected item.
The idea is to get the selected item in proper position by shifting items around in the list.

```
void insertionSort( int[] stuff)
{
   for (int i=1; i< stuff.length; ++i)
   {
      int val = stuff[i];
      int j=i;
      while(j>0&&val<stuff[j-1]){
         stuff[j]=stuff[j-1];
         j--;
      }
      stuff[j]=val;
   }
}
```

Insertion w/primitives

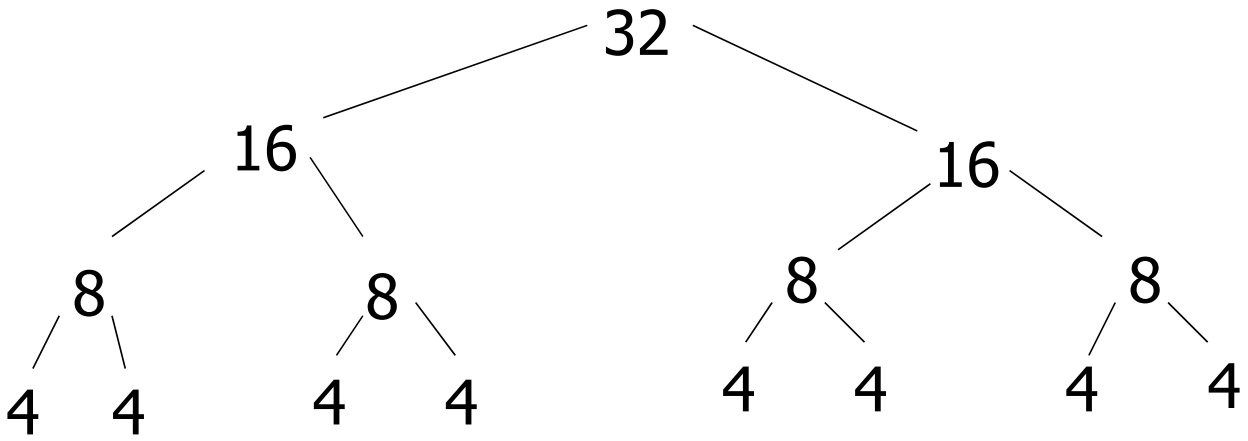
```
void insertionSort( Comparable[] stuff){
  for (int i=1; i< stuff.length; ++i){
    int bot=0, top=i-1;
    while (bot<=top){
      int mid=(bot+top)/2;
      if (stuff[mid].compareTo(stuff[ i ])<0)
        bot=mid+1;
      else top=mid-1;
    }
    Comparable temp= stuff[i];
    for (int j=i; j>bot; --j)
      stuff[ j]= stuff[ j-1];
    stuff[bot]=temp;
  }
}
```

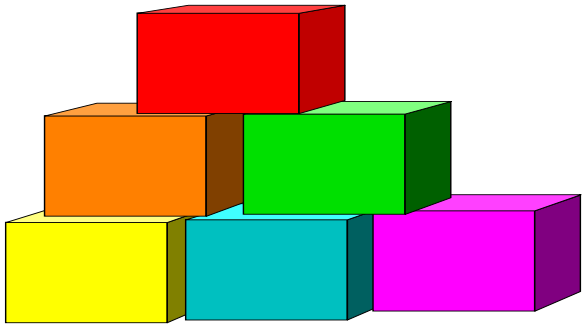
Insertion w/Objects

Divide and Conquer Algorithms

O (N Log2N)

Divide and Conquer



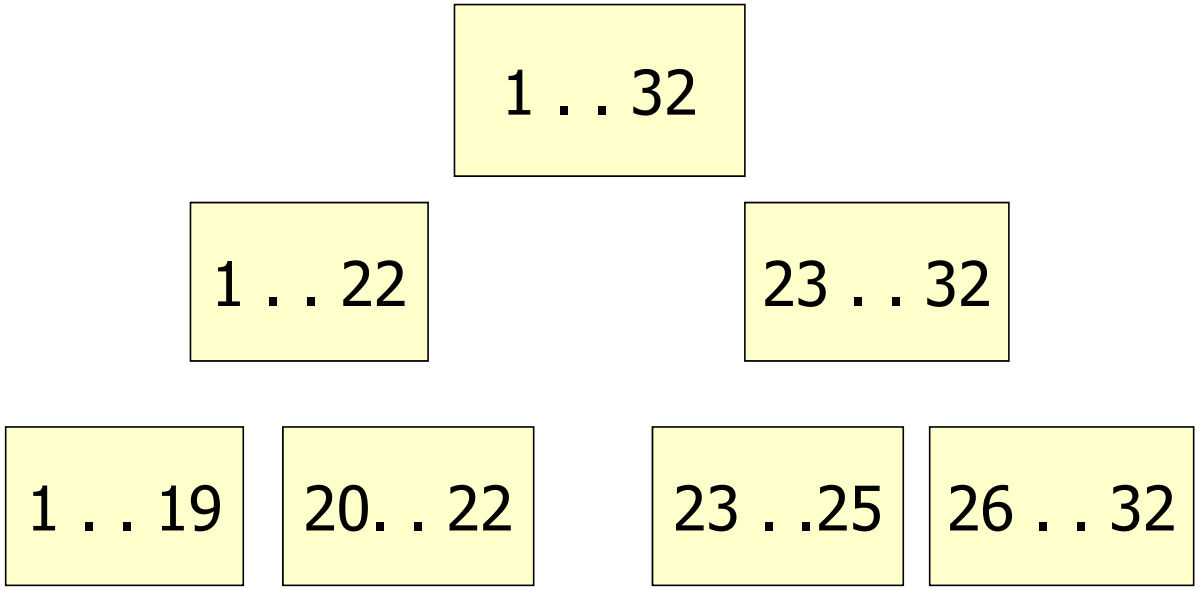


TheQuickSort

Quick Sort

Quick sort finds a pivot value. All numbers greater than the pivot move to the right and all numbers less move to the left. This list is then chopped in two and the process above is repeated on the smaller sections.

Quick Sort



Quick sort chops up the list into smaller pieces as to avoid processing the whole list at once.

quickSort Algorithm

```
void quickSort(Comparable[] stuff, int low, int high)
{
  if (low < high)
  {
    int spot = partition(stuff, low, high);
    quickSort(stuff, low, spot);
    quickSort(stuff, spot+1, high);
  }
}
```

Arrays.sort( ) uses the quickSort
if sorting primitives.

partition Algorithm

```
int partition(Comparable[] stuff, int low, int high)
{
  Comparable pivot = stuff[low];
  int bot = low-1;
  int top = high+1;
  while(bot<top) {
    while (stuff[--top].compareTo(pivot) > 0);
    while (stuff[++bot].compareTo(pivot) < 0);
    if(bot >= top)
      return top;
    Comparable temp = stuff[bot];
    stuff[bot] = stuff[top];
    stuff[top] = temp;
  }
}
```

Quick Sort in Action

Original List

Integer[] ray = {90,40,20,30,10,67};

pass 1 - 67 40 20 30 10 90
pass 2 - 10 40 20 30 67 90
pass 3 - 10 40 20 30 67 90
pass 4 - 10 30 20 40 67 90
pass 5 - 10 20 30 40 67 90

The quickSort has a $N*Log_2N$ BigO.

quickSort

The quickSort method alone has a Log_2N run time, but cannot be run without the partition method.

Partition

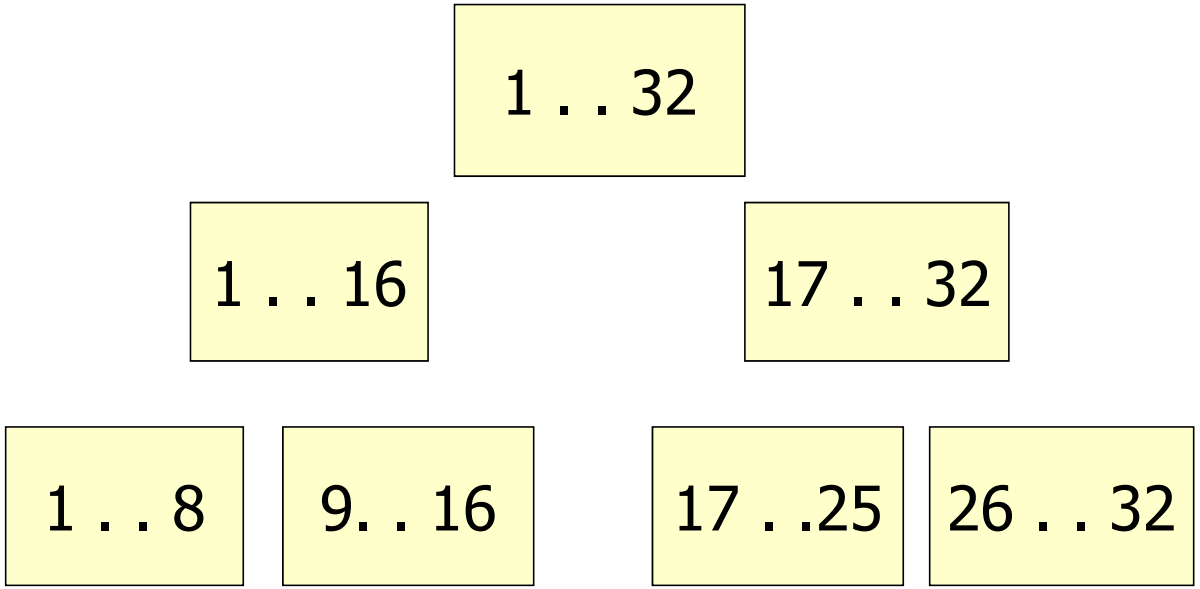
The partition method alone has an N run time and can be run without the quickSort method.


The Merge Sort

Merge Sort

Merge sort splits the list into smaller sections working its way down to groups of two or one. Once the smallest groups are reached, the merge method is called to organize the smaller lists. Merge copies from the sub list to a temp array. The items are put in the temp array in sorted order.

Merge Sort



Merge sort chops in half repeatedly to avoid processing the whole list at once.

mergeSort Algorithm

```
void mergeSort(Comparable[] stuff, int front, int back)
{
   int mid = (front+back)/2;
   if(mid==front) return;
   mergeSort(stuff, front, mid);
   mergeSort(stuff, mid, back);
   merge(stuff, front, back);
}
```

Collections.sort( ) uses the mergeSort.

Arrays.sort( ) uses mergeSort for objects.

```
void merge(Comparable[] stuff, int front, int back)
{
   Comparable[] temp = new Comparable[back-front];
   int i = front, j = (front+back)/2, k =0, mid =j;
   while( i<mid && j<back) {
      if(stuff[i].compareTo(stuff[j])<0)
         temp[k++]= stuff[i++];
      else
         temp[k++]= stuff[j++];
   }

   while(i<mid)
      temp[k++]= stuff[i++];
   while(j<back)
      temp[k++]= stuff[j++];
   for(i = 0; i<back-front; ++i)
      stuff[front+i]=temp[i];
}
```

Merge W/Objects

Merge Sort in Action

Original List

Integer[] stuff = {90,40,20,30,10,67};

pass 0 - 90 20 40 30 67 10
pass 1 - 20 40 90 30 67 10
pass 2 - 20 40 90 30 10 67
pass 3 - 20 40 90 10 30 67
pass 4 - 10 20 30 40 67 90

The mergeSort has a $N*Log_2N$ BigO.

mergeSort

The mergeSort method alone has a Log_2N run time, but cannot be run without the merge method.

Merge

The merge method alone has an N run time and can be run without the mergeSort method.

Speed

Runtime Analysis

```
for( int i=0; i<20; i++)
   System.out.println(i);
```

Which section of code would execute the fastest?

```
for( int j=0; j<20; j++)
   for( int k=0; k<20; k++)
      System.out.println(j*k);
```

Runtime Analysis

```
ArrayList<Integer> iRay;
iRay = new ArrayList<Integer>();
for( int i=0; i<20; i++)
   iRay.add(i);
```

Which section of code would execute the fastest?

```
ArrayList<Double> dRay;
dRay = new ArrayList<Double>();
for( int j=0; j<20; j++)
   dRay.add(0,j);
```

General Big O Chart for N^2 Sorts

Name	Best Case	Avg. Case	Worst
Selection Sort	$O(N^2)$	$O(N^2)$	$O(N^2)$
Bubble Sort	$O(N)$	$O(N^2)$	$O(N^2)$
Insertion Sort	$O(N)$ (@)	$O(N^2)$	$O(N^2)$

@ If the data is sorted, Insertion sort should only make one pass through the list. If this case is present, Insertion sort would have a best case of O(n).

General Big O Chart for NLogN Sorts

Name	Best Case	Avg. Case	Worst
Merge Sort	$O(N \log_2 N)$	$O(N \log_2 N)$	$O(N \log_2 N)$
QuickSort	$O(N \log_2 N)$	$O(N \log_2 N)$	$O(N^2)$ (@)

@ QuickSort can degenerate to N^2. It typically will degenerate on sorted data if using a left or right pivot. Using a median pivot will help tremendously, but QuickSort can still degenerate on certain sets of data. The split position determines how QuickSort behaves.