

## Quick Sort:

157, 110, 147, 102, 111, 149, 151, 141, 123, 112, 117, 123

pivot element = first element

Step 1: pivot = 157

no element greater than 157

$i = \text{left} + 1$

$j = \text{right}$

157 moves till end

so swap 133 with 157

$i = j$

133	110	147	102	111	149	151	141	123	112	117	157
-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----

↑  
pivot

Step 2: pivot = 133

$i = 1, j = 10$

$133 > 110$  (i moves right)

$133 < 147$  (j)

133	110	117	112	111	149	151	141	123	112	147
-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----

$133 > 122$  (move i right)

$112 < 133$

$133 > 111$  (move i right)

$i < j$

$133 > 149$  (loops at  $i = 5$ )

swap (149, 112)

133	110	117	122	111	112	151	141	123	149	147
-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----

↑  
i

↑  
j

133	110	117	122	111	112	123	141	151	149	147
-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----

$123 < 133$

$141 > 133$

swap (pivot, A[j])

$i = 7, j = 6$

$i > j$

123	110	117	122	111	112	133	141	151	149	147
-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----

Step 3: pivot = 123

$i = 2, j = 5$

$110 < 123$

$117 < 123$

$122 < 123$

$111 < 123$

$112 < 123$

j at 5

swap (A[j], pivot)

[112 | 119 | 111 | 122]

pivot = 112

i = 3, j = 4  
119 > 112

[112 | 119 | 111 | 122 | 117]

i = 3, j = 3

i = 3

Swap (111, 119)

[110 | 111]

sorted

[110 | 111 | 112 | 122 | 137]

i = 4, j = 4

pivot = 112

i = j, so swap (112, 112)

[112 | 122]

[110 | 111 | 112 | 122]

pivot = 141

151 > 141

swap 7 pivot

i > j

Swap (pivot, a[j])

(141, 141)

Sorted

[141 | 151 | 141 | 147]

(8-10)

pivot = 151

i = 9, j = 10

149 < 151

142 < 151 (ad i = 10)

swap (151, 147)

[147 | 149 | 151]

Other

Sorted array

[110 | 111 | 112 | 117 | 122 | 123 | 133 | 141 | 149 | 151 | 157]

last element as pivot.

157 | 110 | 147 | 122 | 111 | 149 | 151 | 141 | 123 | 119 | 133 |  
↑  
pivot

pivot = last

i = low

j = high - 1

if  $i < j$  swap  $A[i]$  &  $A[j]$

if  $i \geq j$  swap  $A[i]$  & pivot

Step 2

Partition (0-4)

pivot = 133

i = 0 j = 4

157 > 133 (stops at i = 0) 119 < 133

Swap (157 ↔ 119).

119 | 110 | 147 | 122 | 111 | 149 | 151 | 141 | 123 | 112 | 157 | 133 |  
↑  
pivot

110 < 133

147 > 133 (stop at i = 2)

swap (147, 122)

119 | 110 | 122 | 147 | 111 | 149 | 151 | 141 | 123 | 112 | 157 | 133 |

112 < 133

111 < 133

149 > 133

swap (149, 123)

119 | 110 | 112 | 111 | 123 | 151 | 140 | 149 | 157 | 133 |

123 < 133

140 > 133

149 > 133

141 > 133

151 > 133

123 < 133

119 | 110 | 112 | 122 | 111 | 123 | 133 | 141 | 149 | 147 | 157 | 151 |

pivot 133 fixed.

Step 3

left (0-5)

pivot = 23

i = 0, j = 5

118 > 112  
 118 > 112  
 118 > 112  
 (110 | 111 | 112 | 113 | 114 | 115)

111 > 110  
 111 > 110  
 111 > 110

(110 | 111 | 112 | 113 | 114 | 115)

111 > 110 (stop at 110)  
 111 > 110 (stop at 110)

(110 | 111 | 112 | 113 | 114 | 115)

111 > 110  
 111 > 110  
 111 > 110  
 111 > 110 (stop)  
 111 > 110 (stop)

(110 | 111 | 112 | 113 | 114 | 115)

111 > 110  
 (110 | 111 | 112 | 113 | 114 | 115)

111 > 110

111 > 110

111 > 110

111 > 110

111 > 110

(110 | 111 | 112 | 113 | 114 | 115)

111 > 110  
 111 > 110

111 > 110

111 > 110 (stop)

111 > 110 (stop)

Final array: (110 | 111 | 112 | 113 | 114 | 115 | 116 | 117 | 118 | 119 | 120)

Random element as pivot element

choose Random swap with first element

157	110	149	122	111	140	151	141	123	112	117	183
-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----

Step 1      Take 141 pivot  
Swap with first

141	110	149	122	111	140	151	157	123	112	117	183
-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----

Pass 1      i stop at 149  
j stop at 183

141	110	183	122	111	149	151	157	123	112	117	147
-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----

Pass 2      7 stop at 149      Sweep 149 117  
3 stop at 183

141	110	183	122	111	147	151	123	112	149	147
-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----

Pass 3      i stop at 151  
j stop at 112

141	110	183	122	111	117	112	157	123	151	149	147
-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----

Pass 4      i stop 157  
3 stop at 123

123	110	183	122	111	117	112	141	157	151	149	157
-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----

pivot index = 7

call subarray [0, 6]

Step 2

Pass 1

123	110	183	122	111	117	112
-----	-----	-----	-----	-----	-----	-----

After swap      

117	110	183	122	111	123	112
-----	-----	-----	-----	-----	-----	-----

pen 2 : stop at 122

3 stop at 111

swap 122  $\leftrightarrow$  111

[117 | 110 | 112 | 111 | 122 | 123 | 133]

pen 3

$i = 31$

[11 | 110 | 112 | 112 | 122 | 123 | 133]

Left Subarray [0, 2]

Step 3

Subarray [0, 2] - left at 117

Take pivot = 110

Swap with 111

[110 | 111 | 112]

pen 2

$i = 1, j = 2$

print at 141 [157 | 151 | 149 | 147]

Step 4: Subarray [8, 11] [157 | 151 | 149 | 147]

Take pivot = 149

Swap with 152

[149 | 151 | 157 | 147]

pen 1:

$i = 9$   
 $j = 11$

Swap 147  $\leftrightarrow$  151

[149 | 147 | 157 | 151]

pen 2

$i = 10$   
 $j = 9$

swap 149  $\leftrightarrow$  147 [147 | 149 | 157 | 151]

Step 5

Right at 149 [10, 11]

after swap 151 157

Final [110 | 111 | 112 | 117 | 122 | 123 | 133 | 141 | 147 | 149 | 151 | 157]