By this time, you should have seen at least one solution to the 2-color Dutch National Flag problem. Here you are asked to develop a solution to the slightly more complicated 3-color version of the problem. Your program is not to modify the array except by swapping array elements. (Assume that there is a method swap such that the effect of making the call swap(a, k, j) is to swap the values in a[k] and a[j].)

The precondition is that each element in the array a[0..N - 1] (we use N as an abbreviation for the length of a, which in Java is written a.length) qualifies as being either RED, WHITE, or BLUE. The postcondition is as indicated in this picture:

```
|   0   |   r   |   w   |   N   |
|-----------------------------------|
| a | all RED | all WHITE | all BLUE |
```

In words, this says that every element in a[0..r - 1] is RED, every element in a[r..w - 1] is WHITE, and every element in a[w..N - 1] is BLUE. More formally, we could express this in the language of predicate logic as follows:

\((\forall i \mid 0 \leq i < r : a[i] \text{ is RED}) \land (\forall i \mid r \leq i < w : a[i] \text{ is WHITE}) \land (\forall i \mid w \leq i < N : a[i] \text{ is BLUE})\)

The loop invariant of your program should be as indicated in this picture:

```
|   0   |   r   |   w   |   b   |   N   |
|-----------------------------------------------|
| a | all RED | all WHITE |   ?   | all BLUE |
```

In words, this says that every element in a[0..r - 1] is RED, every element in a[r..w - 1] is WHITE, and every element in a[w..N - 1] is BLUE. (Notice that we obtained the invariant by replacing w in the second conjunct of the postcondition by the "fresh" variable b.) More formally, we can express this by

\((\forall i \mid 0 \leq i < r : a[i] \text{ is RED}) \land (\forall i \mid r \leq i < w : a[i] \text{ is WHITE}) \land (\forall i \mid b \leq i < N : a[i] \text{ is BLUE})\)

Arrive at your solution by correctly replacing each question mark in the following with either an expression or a sequence of statements, whichever is appropriate. The initialization of r, w, and b should establish the invariant by making the ?-region cover the entire array. Each iteration of the loop should decrease the length of the ?-region while at the same time preserving the truth of the loop invariant.

```
r = ?;  w = ?;  b = ?;
while ( ? )
{
    if (a[ ? ] is RED) {

    }

    ?
```
} else if (a[?] is WHITE) {

? 
}
else /* a[?] is BLUE */ {

? 
}
}