# Garbage Collection

**Free list**: 10 → 11 → 4 → 13 → 12

**Table**:

<table>
<thead>
<tr>
<th>Free list</th>
<th>0</th>
<th>10</th>
<th>12</th>
<th>4</th>
<th>6</th>
<th>3</th>
<th>8</th>
<th>7</th>
<th>8</th>
<th>3</th>
<th>11</th>
<th>14</th>
<th>12</th>
<th>13</th>
<th>14</th>
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</table>

**Notes**:
- The diagram shows a memory layout with nodes labeled a, b, c, etc.
- The table tracks free list positions and addresses (leftmost column labeled "address", rightmost column labeled "right").
Run the garbage collection algorithm when there's nothing on Free list.

So it's crucial to minimize space used by the garbage collection algorithm.
Mark & Sweep Algorithm

**Mark Phase**  Search through reachable memory (non-garbage) & mark the cells you can reach.

**Sweep Phase**  Sweep through all memory

  - if marked → unmark
  - if unmarked → add to front of free list
breadth-first search

depth-first search can both find all vertices reachable from a given source

Before garbage collection
Use DFS - temporarily modify memory cells to maintain stack

Before garbage collection

Stack: 1 2 3 4 5
Let's see how we can restore memory

Stack: 6, 5, 4, 3, 2, 1
In-place DFS

3 cases

Go deeper into search

retreat back to your "parent" in stack

Combine

retreat
goto deeper to right
Time Complexity

\[ M = \# \text{ memory cells} \]

\[ A = \# \text{ of accessible (reachable) cells} \]

**time for mark phase:** \( O(A) \)

**dfs (**) \( O(n + m) \)**

\[ A \leq 2A \]

**time per cell:** \( O\left(\frac{M + A}{M - A}\right) \)

**time for sweep phase:** \( O(\text{CM}) \)
Copying Collection

Divide memory into two halves

we say to use $M/2$

memory cells
Phase 2
Time complexity

Phase 1: $O(A)$

Phase 2: $O(A)$

cells now on free list $\frac{M}{2} - A$
Time Complexity

\[ O(A) \]

Cost of garbage collection

\[ \frac{\text{# cells freed}}{M/2 - A} \]

Mark & Sweep

\[ O \left( \frac{A + M}{M - A} \right) \]