# CSc 520

# Principles of Programming Languages

## *41: Garbage Collection — Generational Collection*

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# Generational Collection

- Works best for functional and logic languages (LISP, Prolog, ML, . . . ) because
  1. they rarely modify allocated cells
  2. newly created objects only point to older objects (`(CONS A B)` creates a new two-pointer cell with pointers to old objects),
  3. new cells are shorter lived than older cells, and old objects are unlikely to die anytime soon.



# Generational Collection. . .

- Generational Collection therefore
  1. divides the heap into generations, $G_0$ is the youngest, $G_n$ the oldest.
  2. allocates new objects in $G_0$.
  3. GC's only newer generations.
- We have to keep track of back pointers (from old generations to new).



# Generational Collection. . .

Functional Language:

```
(cons 'a '(b c))
        ⇕
t1:  x ← new '(b c);
t2:  y ← new 'a;
t3:  return new cons(x, y)
```

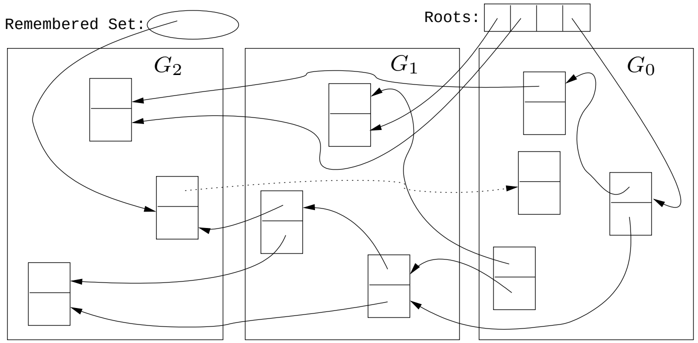
- A new object (created at time $t_3$) points to older objects.

Object Oriented Language:

```
t1:  T ← new Table(0);
t2:  x ← new Integer(5);
t3:  T.insert(x);
```

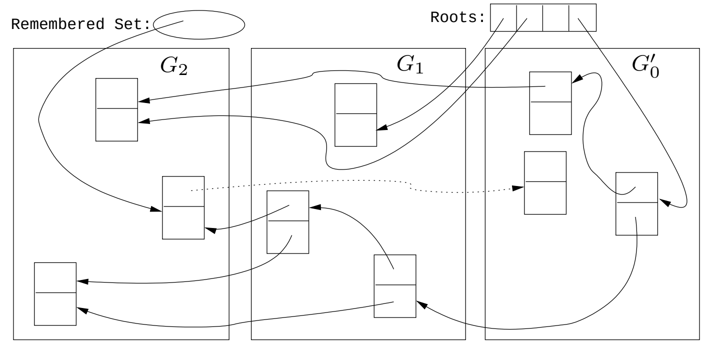
- A new object (created at time $t_2$) is *inserted into* an older object, which then points to the news object.

# Generational Collection…






# Generational Collection – After GC($G_0$)






# Generational Collection…

- Since old objects (in $G_n \cdots G_1$) are rarely changed (to point to new objects) they are unlikely to point into $G_0$.
- Apply the GC only to the youngest generation ($G_0$), since it is most likely to contain a lot of garbage.
- Use the stack and globals as roots.
- There might be some back pointers, pointing from an older generation into $G_0$. Maintain a special set of such pointers, and use them as roots.
- Occasionally GC older ($G_1 \cdots G_k$) generations.
- Use either mark-and-sweep or copying collection to GC $G_0$.



# Remembering Back Pointers

# Remembering Back Pointers

## Remembered List

After each pointer update `x.f := ···`, the compiler adds code to insert x in a list of updated memory locations:

```
x↑.f := ···
      ⇓
x↑.f := ···;
insert(UpdatedList, x);
```



# Remembering Back Pointers

## Remembered Set

As above, but set a bit in the updated object so that it is inserted only once in the list:

```
x↑.f := ···
      ⇓
x↑.f := ···;
IF NOT x↑.inserted THEN
   insert(UpdatedList, x);
   x.↑inserted := TRUE;
ENDIF
```



# Remembering Back Pointers...

## Card marking

- Divide the heap into "cards" of size $2^k$.
- Keep an array `dirty` of bits, indexed by card number.
- After a pointer update `x↑.f := ···`, set the dirty bit for card c that x is on:

```
x↑.f := ···
      ⇓
x↑.f := ···;
dirty[x div 2^k] := TRUE;
```



# Remembering Back Pointers...

## Page marking I

- Similar to Card marking, but let the cards be virtual memory pages.
- When x is updated the VM system automatically sets the `dirty` bit of the page that x is on.
- We don't have to insert any extra code!

# Remembering Back Pointers. . .

Page marking II

- The OS may not let us read the VM system's dirty bits.
- Instead, we write-protect the page x is on.
- On an update `x↑.f := ···` a protection fault is generated. We catch this fault and set a dirty bit manually.
- We don't have to insert any extra code!



# Readings and References

- Read Scott, pp. 395–401.