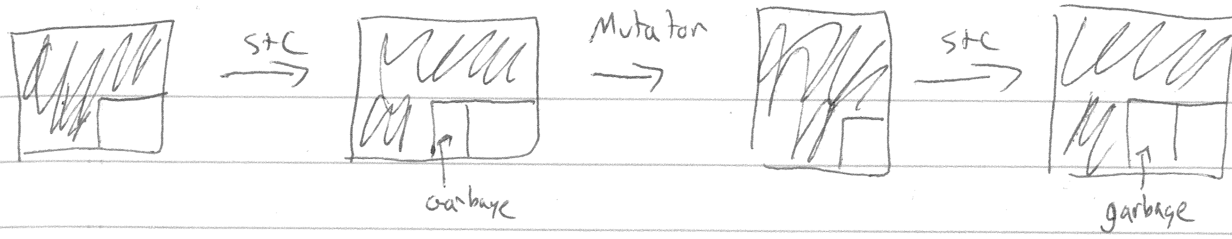
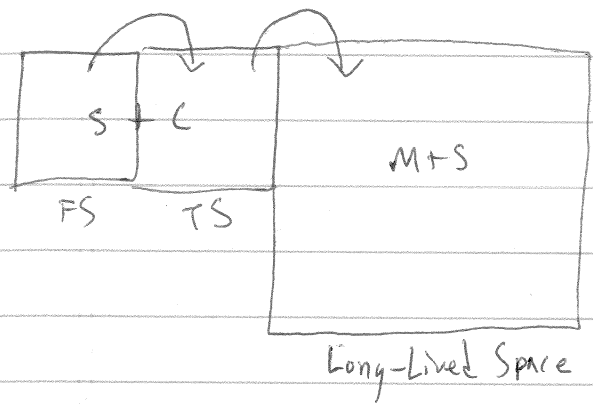
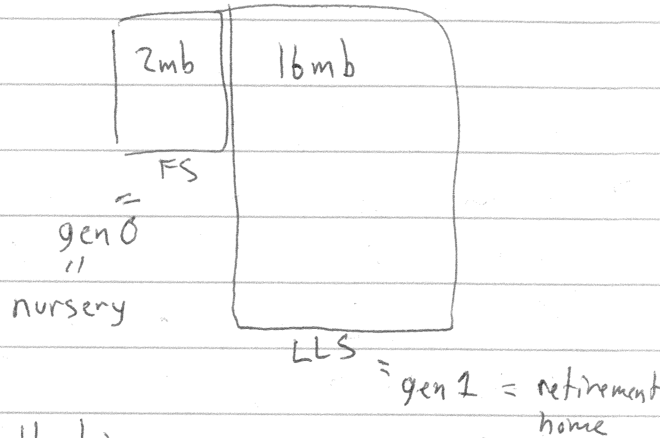
12-2) Long-lived things are copied a lot

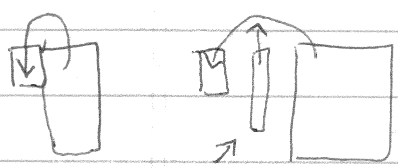






Generational Collection

"most objects die young"



do S+C often, do M+S sparingly

Inter-generational Pointer Table

ssssMssss M
↓ igpt1 ↓ igpt2

Program: o.f = x

now:

write barrier

```
if x is new
  && o is old
    igpt.add(o, x)
o.f = x
```

G.G.C: mem is as M+S & IGPT

time is as S+C + write barriers

Radioactive decay model

5-1

```
int main (int argc, char ** argv) {
    return main(argc, argv);
}
```

= Stack Overflow

$\Omega = ((\lambda x.\,(x\ x))\ (\lambda x.\,(x\ x)))$ $\quad w = \lambda x.\,x\,x$

$\Omega \to_\beta \Omega$

$\langle \Omega, \emptyset, mt \rangle$

$\langle w, \emptyset, \langle ar, w, \emptyset, mt \rangle \rangle$ $\quad c = \langle w, \emptyset \rangle$

$\langle w, \emptyset, \langle fn, \langle w, \emptyset \rangle, mt \rangle \rangle$

$\langle (x\ x), [x \mapsto c], mt \rangle$

$\langle x, [x \mapsto c], \langle ar, x, [x \mapsto c], mt \rangle \rangle$

$\langle c, [x \mapsto c], \langle ar, x, [x \mapsto c], mt \rangle \rangle$

$\langle x, [x \mapsto c], \langle fn, x, \langle w, \emptyset \rangle, mt \rangle \rangle$

$\langle c, \text{''}, \text{''} \rangle$

$\langle (x\ x), [x \mapsto c], mt \rangle$

constant space

SECD machine

S - stack (not all like K)

E - env (same as CEK)

C - control string (very similar to CEK's C)

D - dump (saved SECD)

Stack-Machine

3 4 +

7

5 3 4 + *

35

$\langle S, E, (M\ N)\ C, D \rangle \longmapsto \langle S, E, M\ N\ ap\ C, D \rangle$

$\langle S, E, (\lambda X.M)\ C, D \rangle \longmapsto \langle \langle (\lambda X.M), E \rangle\ S, E, C, D \rangle$

$\langle S, E, b\ C, D \rangle \longmapsto \langle b\ S, E, C, D \rangle$

$\langle S, E, X\ C, D \rangle \longmapsto \langle E(X)\ S, E, C, D \rangle$

$\langle V\ \langle \lambda X.M, E_{clo} \rangle\ S, E, ap\ C, D \rangle$

$\longmapsto \langle \varepsilon, E_{clo}[X \mapsto V], M, \langle S, E, C, D \rangle \rangle$

$\langle V\ S, E, \varepsilon, \langle S', E', C', D' \rangle \rangle$

$\longmapsto \langle V\ S', E', C', D' \rangle$

15-2 $\Omega = (w\ w) \qquad w = (\lambda x.\, x\,x)$

$c = \langle w, \emptyset \rangle$

bytecode compiler $\downarrow$ $\quad C$ = bytecode

$\lfloor \Omega \rfloor = \lfloor w \rfloor \lfloor w \rfloor$ ap

$\lfloor w \rfloor = (\lambda x.\, x\ x\ ap)$

$\langle \varepsilon, \emptyset, \Omega, mt \rangle$

$\mapsto \langle \varepsilon, \emptyset, w\ w\ ap, mt \rangle$

$\mapsto \langle \langle w, \emptyset \rangle, \emptyset, w\ ap, mt \rangle$

$= \langle c, \emptyset, w\ ap, mt \rangle$ useless

$\mapsto \langle \langle c, c \rangle, \emptyset, ap, mt \rangle$

$\mapsto \langle \varepsilon, [x \mapsto c], (x\ x), \langle \varepsilon, \emptyset, \varepsilon, mt \rangle \rangle$

$\to \langle \varepsilon, [x \mapsto c], x\ x\ ap, \text{¶} \rangle$

$\mapsto \langle c, [x \mapsto c], x\ ap, \text{¶} \rangle$

$\mapsto \langle \langle c, c \rangle, [x \mapsto c], ap, \text{¶} \rangle$

$\mapsto \langle \varepsilon, [x \mapsto c], (x\ x), \langle \varepsilon, [x \mapsto c], \varepsilon, \text{¶} \rangle \rangle$

$(\lambda x.\, x\,x\,ap)\ (\lambda x.\, x\,x\,ap)\ ap$

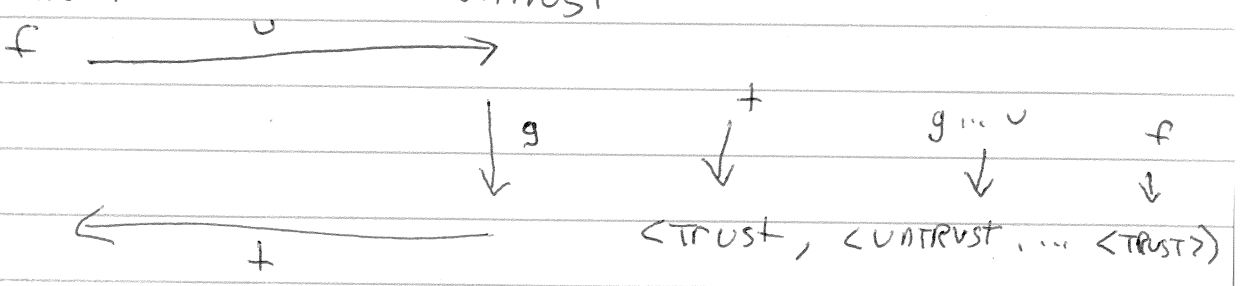
useless

CEK allocates on arg evaluation, frees on fun calls

SECD allocs on calls and arg eval $\quad = O(a+c)$ $\quad "\ O(a)$

$(F\ F)\ 0)$

$= (\lambda f.\, (\lambda x.\, ((f\,f)\,(\lambda x.\, x))))$



① $\langle (M\ N), E, K \rangle \overset{ack}{\mapsto} \langle M, E, \langle ar, N, E, K \rangle \rangle$

② $\langle (\lambda x.\, M), E, K \rangle \mapsto \langle \langle (\lambda x.\, M), E \rangle, E, K \rangle$

$E|_S = E$ ~~except~~ only S (restricting E to S)

$\{x \mapsto 1, y \mapsto 2\}|_{\{x\}} = \{x \mapsto 1\}$

"safe for space"

① $\mapsto \langle M, E|_{FV(M)}, \langle ar, N, E|_{FV(N)}, K \rangle \rangle$

② $\mapsto \langle \langle (\lambda x.\, M), E|_{FV(M)} \rangle, \emptyset, K \rangle$ ↑ prevents sharing

(c.f. "flat closures")