Intro to Lab 3

04/21/22

Misc

- Lab 3 is out
  - Due 3 weeks from now
  - Design doc due next week

Today's Agenda

- High level intro for Lab 3 - Address Management
  - Take a look into `vspace.c` functions you'll need on your own
- Next week - deeper dive into vspace structs and functions

Part 1: User Level Heap

- User-level programs use **malloc** and **free** to manage heap memory
  - Track list of the free blocks in memory
  - **Malloc:** Return a free block of memory somewhere in the heap
  - **Free**: Free a block of memory somewhere on the heap, so it can be reused
  - **Calloc:** Malloc, but zeros out the block before returning it
  - We've given you malloc/free in **user/umalloc.c**
    - Or you could paste in your implementation from 351 (actually, please don't)
- But that's not everything
  - What happens if we run out of memory on the heap for malloc to use?
  - Malloc deals with virtual memory, but we need to map it to physical data

sbrk

("set program break")
Get more heap space

sbrk(n)

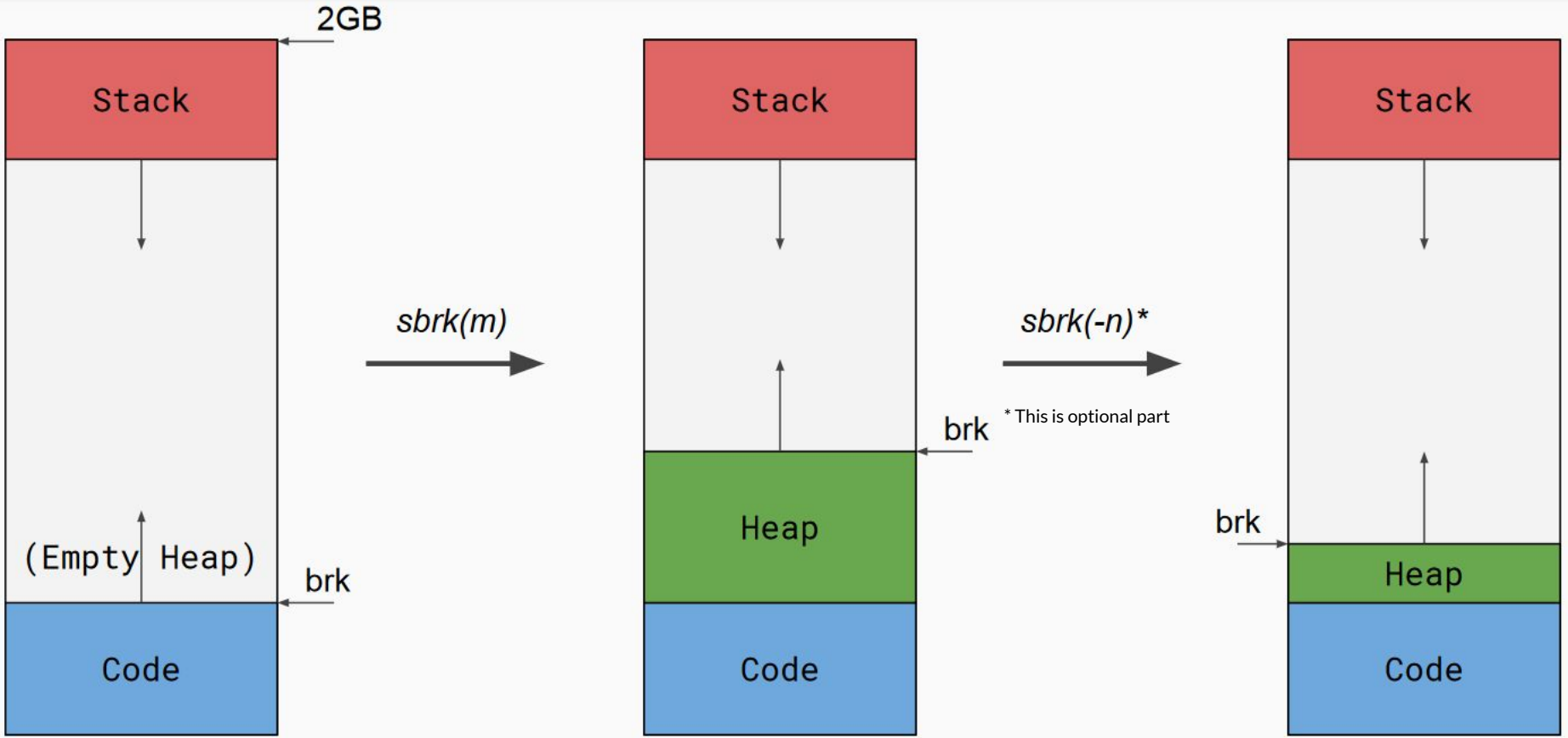
Increase the size of the heap by *n* bytes, updating the “program break”

Program break = max space allocated to the heap data segment

N can be negative in a real system, but that doesn’t matter for xk

Returns -1 if it can’t allocate enough space

Otherwise, return the *previous* heap limit (the old top of the heap)


2GB
Stack
(Empty Heap)
brk
Code
sbrk(m)
Stack
brk
Heap
Code
sbrk(-n)*
* This is optional part
Stack
brk
Heap
Code

Sbrk details

- Sbrk should allocate at **byte** granularity (may need to allocate 0, 1, or multiple new pages)
- New pages need to be properly mapped into the process' address space
- Use vspaceaddmap to get new pages

Once implemented, malloc/free tests should pass

The Shell

Running multiple programs

Shell

- The initial process (user/init.c) will fork to create a shell
- The shell will take user input and run commands, spawning other programs
  - Just like bash, cmd, or whatever else
- Shell will spawn other programs
- You can use the shell to pipe things
  - e.g. **ls | wc** will pipe the output of ls into the input of wc
  - Since fd 0/1/2 are always in/out/err, we can change a process file table entry to be a pipe (when forking, before exec)

Let it Grow

more stack

The Stack

- The initial version of exec is pretty simple
  - It fixed the stack size at one page
- One page of stack probably isn't enough for larger programs
- We want to be able to add more pages of stack.

How do we tell when more stack needs to be added?

- Once we've written off the end of what's currently allocated
  - PAGE FAULT!
  - Add more pages and resume user-level execution
- For simplicity, you can assume the stack will never need more than 10 pages
  - If page fault and address > stack_base - 10: grow stack; else: "normal" page fault (can't handle)

Grow Stack on Demand

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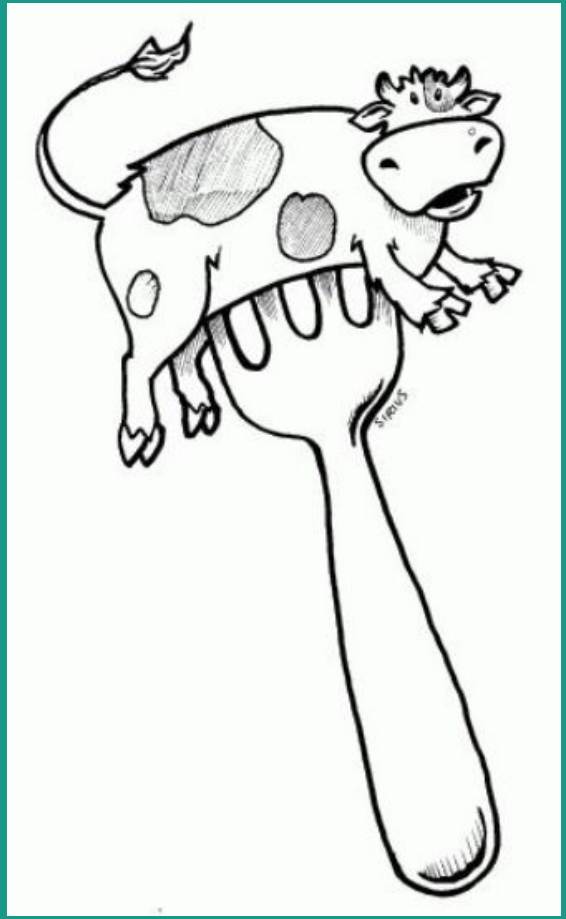
- Functions similarly to sbrk
  - Adding pages to particular region, but signal is different

COW Fork

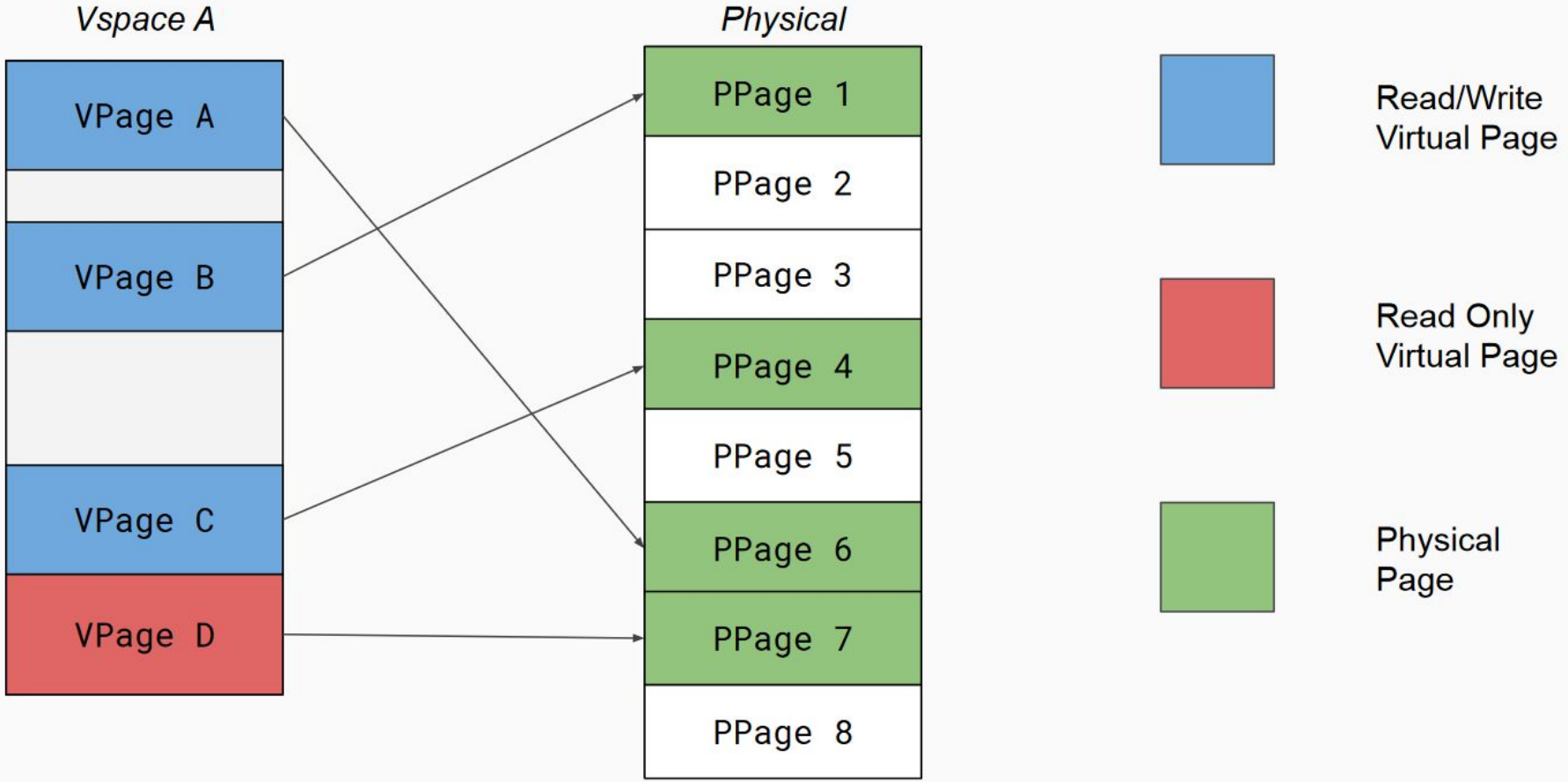
(beef utensils)

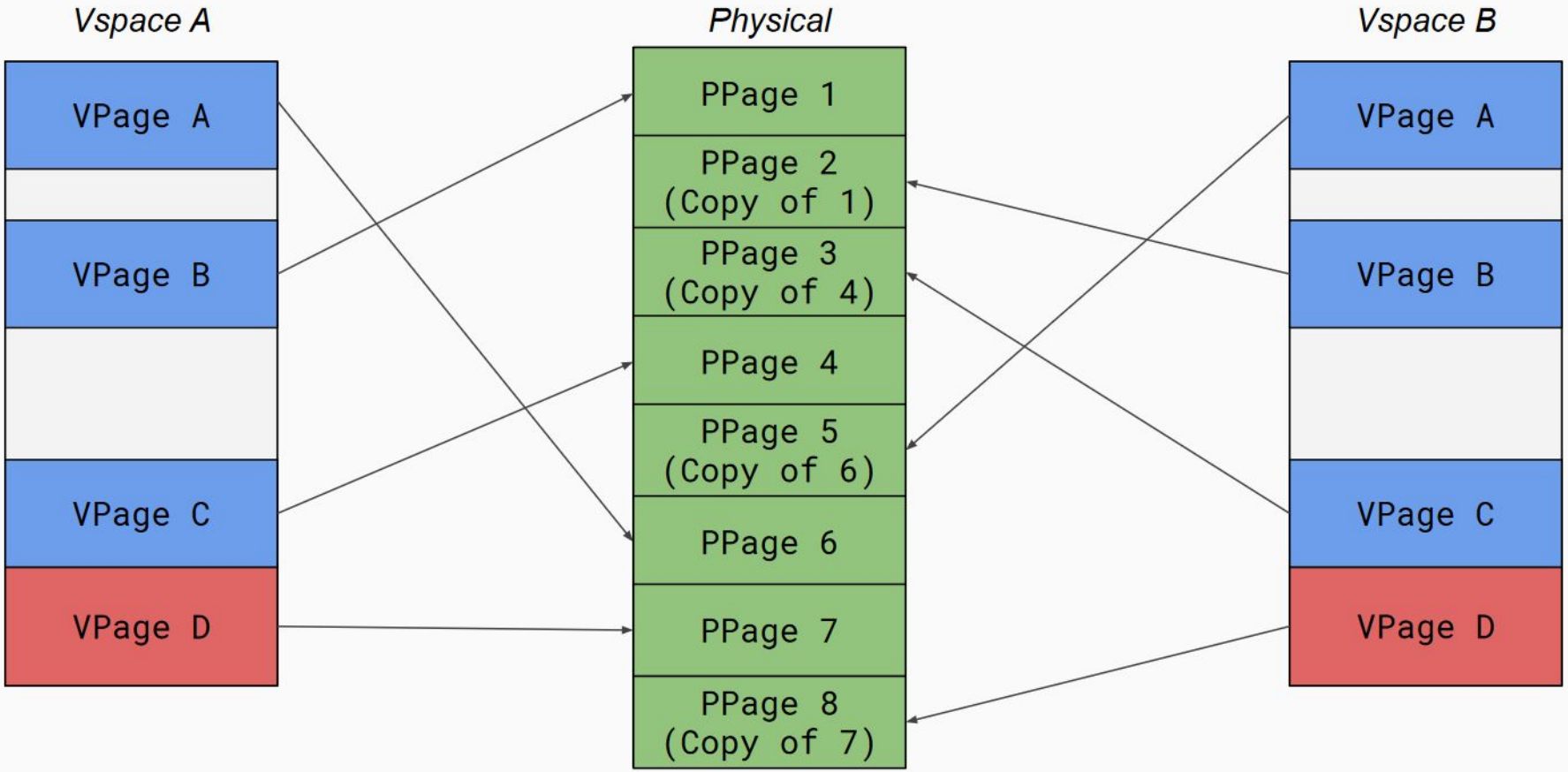


Copy on Write Fork

The lab 2 fork implementation is inefficient.

Vspacecopy completely memcpys all pages, so the parent and child have disjoint page tables


Vspace A
VPage A
VPage B
VPage C
VPage D
Physical
PPage 1
PPage 2
PPage 3
PPage 4
PPage 5
PPage 6
PPage 7
PPage 8
Read/Write Virtual Page
Read Only Virtual Page
Physical Page


Vspace A
VPage A
VPage B
VPage C
VPage D
Physical
PPage 1
PPage 2
(Copy of 1)
PPage 3
(Copy of 4)
PPage 4
PPage 5
(Copy of 6)
PPage 6
PPage 7
PPage 8
(Copy of 7)
Vspace B
VPage A
VPage B
VPage C
VPage D

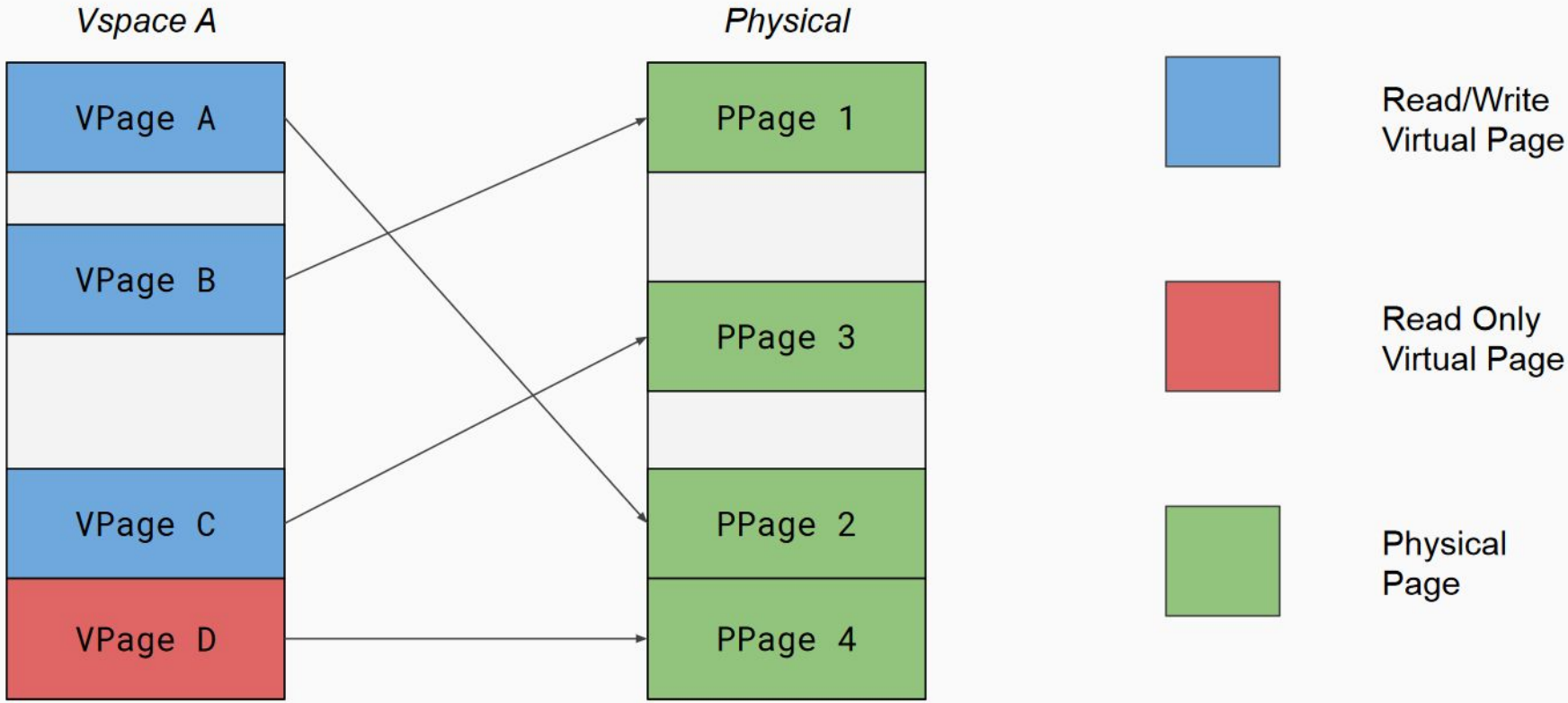
We copied all the pages :(

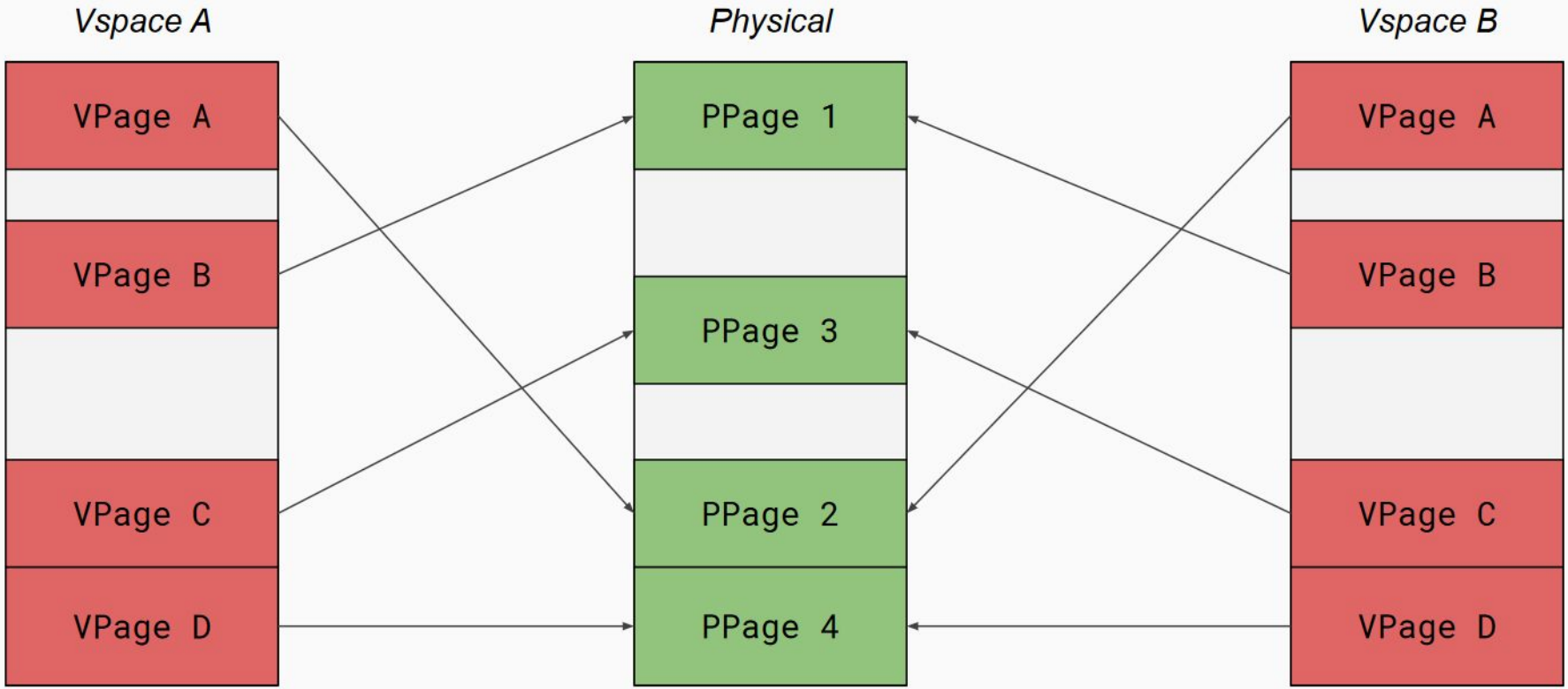
As a consequence:

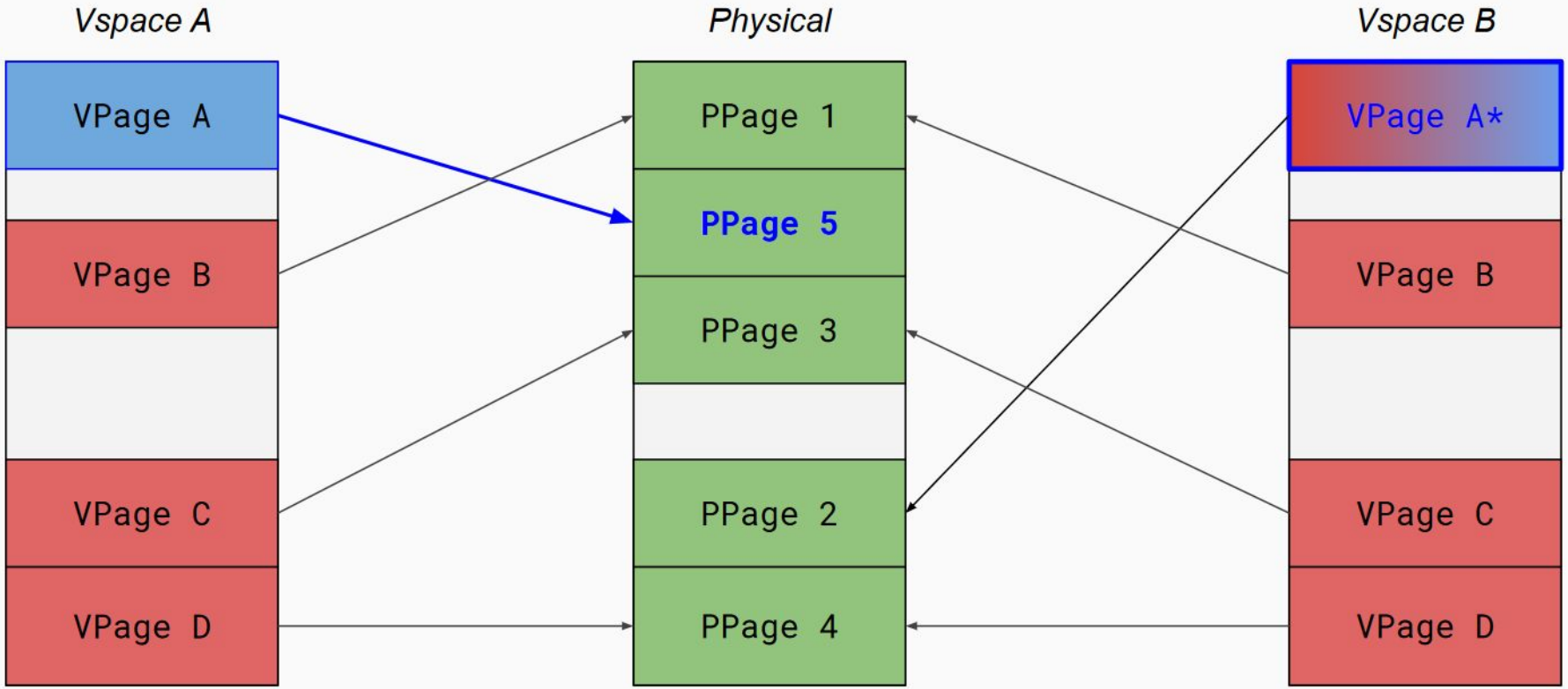
- Child and parent duplicate the same unchanging pages of code and static data
- If we fork and exec, we waste time copying all pages before immediately discarding the vspace

How would we optimize this to reduce the memory footprint of processes? What can we do better?

- Don’t actually copy pages
- Clone the page table and set everything to read-only
    - Both processes can reference the same data
    - Don’t actually copy pages
- Only when we need to write to a page should we duplicate it
    - Most of the time, we won’t write to a page again, so no copying needs to be done


Vspace A
Physical
VPage A
VPage B
VPage C
VPage D
PPage 1
PPage 3
PPage 2
PPage 4
Read/Write
Virtual Page
Read Only
Virtual Page
Physical
Page


Vspace A
VPage A
VPage B
VPage C
VPage D
Physical
PPage 1
PPage 3
PPage 2
PPage 4
Vspace B
VPage A
VPage B
VPage C
VPage D



VPage A in B could be safely set to writable (if there are no other vpsace pointers to PP2).
When VSpaceB::A gets set back to writable is an implementation detail

Things to Consider

1. How do you distinguish a copy-on-write read-only page from a normal read-only page?
2. Make sure that no memory is leaked
    a. If the reference count of a physical COW page is 1, the process with that reference can reclaim it as non-COW
3. What happens (specifically) when a process tries to write to a COW page?
    a. For starters, a tried-to-write-to-read-only page fault
4. Synchronization is necessary
    a. Parent and child could try to write at the same time
5. A child with COW pages can fork to create another child
    a. Parent, child, grandchild, etc. all referencing the same physical pages

Design Doc

- You got your feedback for lab 2 design.
- How did your design end up different from your implementation?
- How's that going to change how you do lab3 design?

Thoughts, feedback?