Code Generation

Martin Kellogg

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  - Review session: tonight at 5pm (virtually)
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- Hopefully you started PA3c3 over break
  - its due date is **one week from today**

Agenda

- Last time, all the way before the break:
  - Stack machine basics
    - accumulator, stack pointer
  - Stack discipline, calling convention for our stack machine
    - with a bit of optimization thrown in to give you a taste of the idea
- Today:
  - Quick review
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    - Always points to the return address on the stack
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    - It doesn’t move => args on the stack are at a fixed offset

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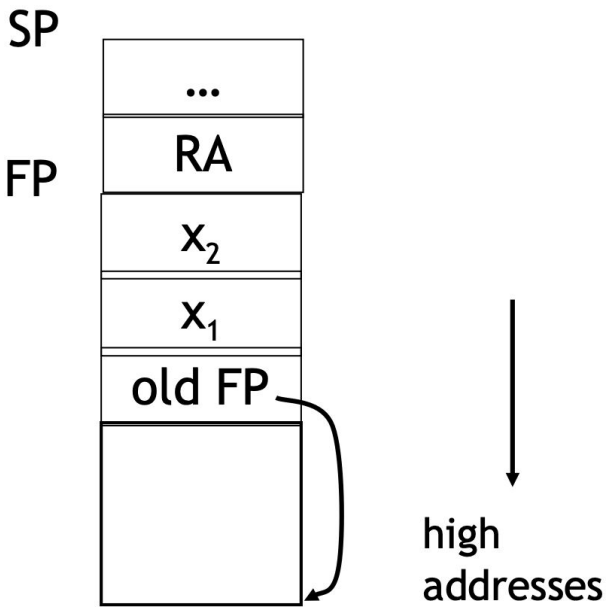

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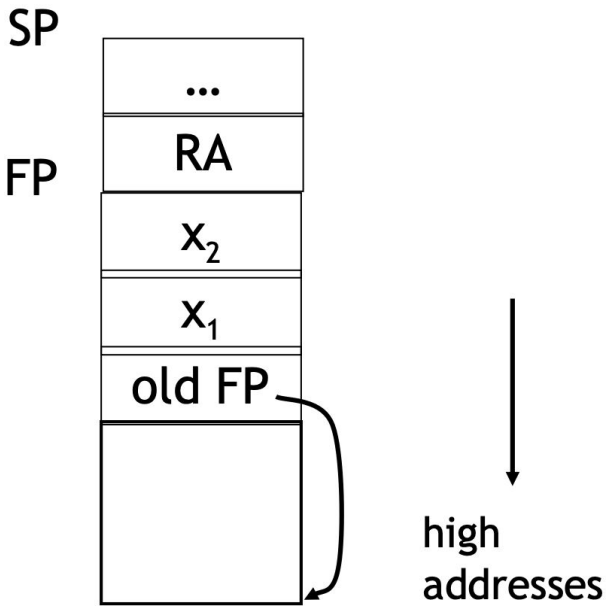

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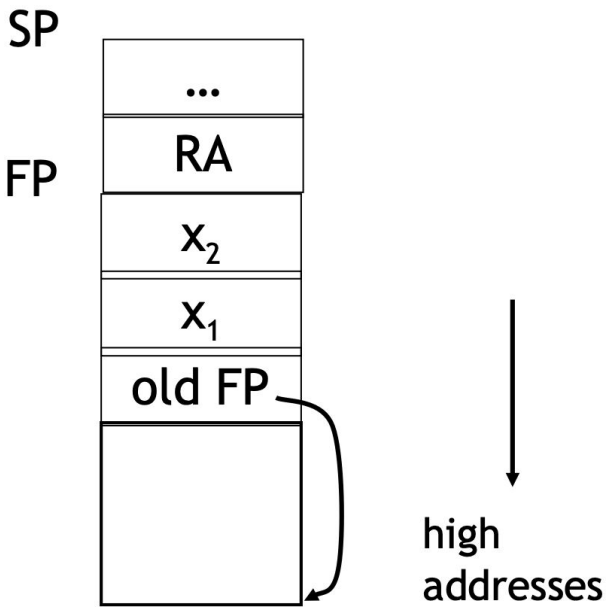

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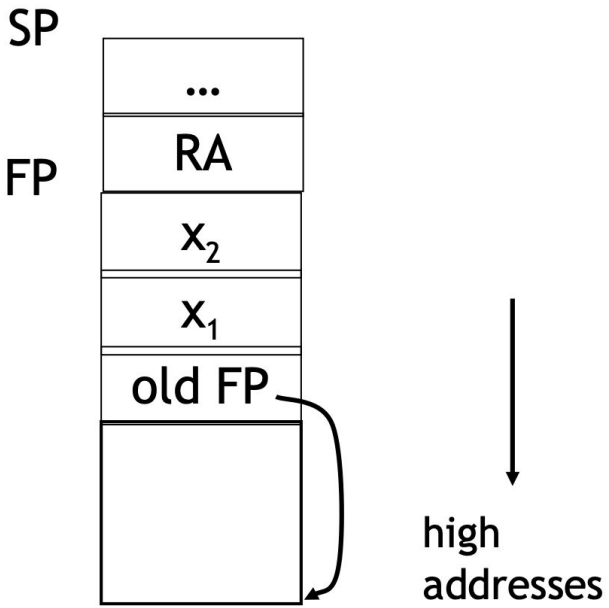

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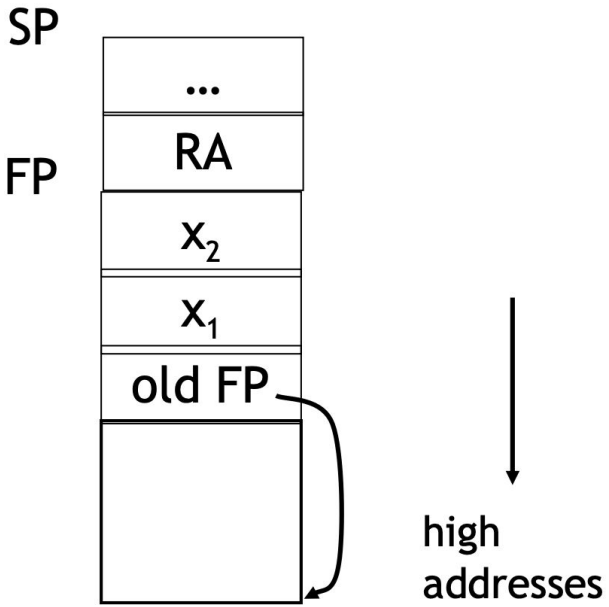

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- where $z \approx n+1 - i$

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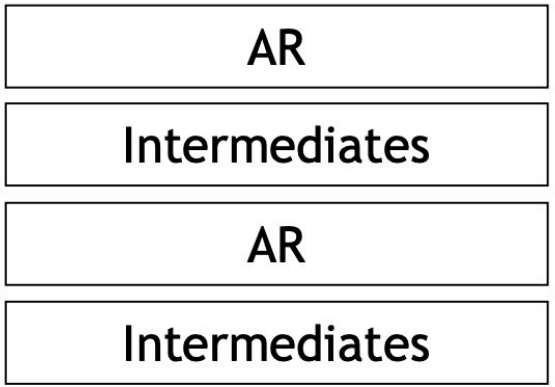

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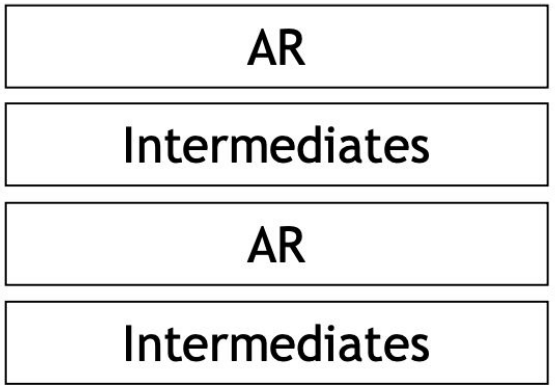

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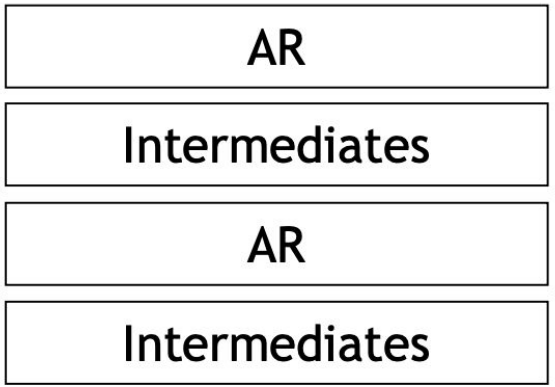
  - Advantage: **Very simple** code generation (great for PA3)
  - Disadvantage: **Very slow** code (bad for PA4)
    - Storing and loading temporaries requires a store/load and sp adjustment



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  - **How many** slots are needed in the AR to hold these values?

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In class exercise: what is ***NT***(def fib(x) =
  if x = 1 then 0 else
    if x = 2 then 1
    else fib(x - 1) + fib(x – 2))?

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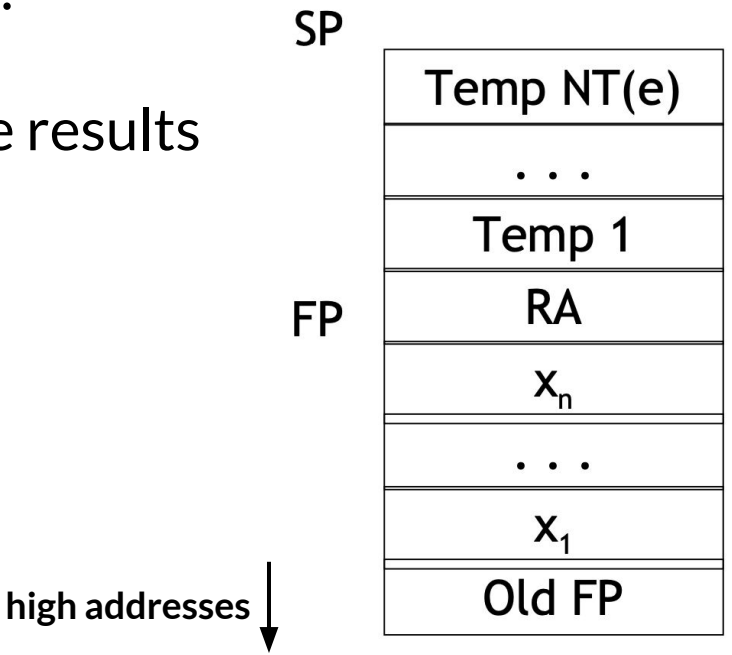

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cgen(e, n) : generate code for e and use temporaries whose address is (fp - n) or lower

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Where are the savings?
(Hint: “push” is more expensive than it looks…)

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- Hint: on function entry, you'll have to increment something by ***NT***(e)
  - ... and on function exit, decrement it ...

Trivia Break: ??

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  - This means that code in class A **must work unmodified** on an object of class B

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  - Objects are laid out in **contiguous memory**
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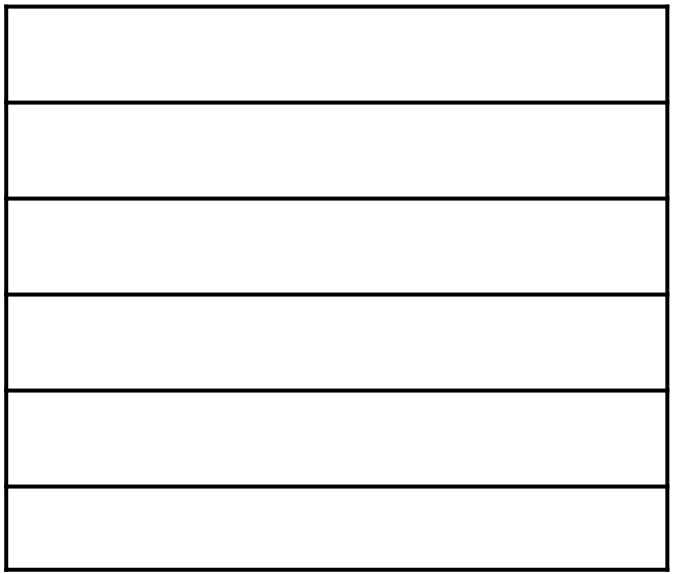
  - When a method is invoked, the object becomes self and the fields are the object's attributes

Cool Object Layout

- The first three words of each Cool object contains ***header information***:

Offset



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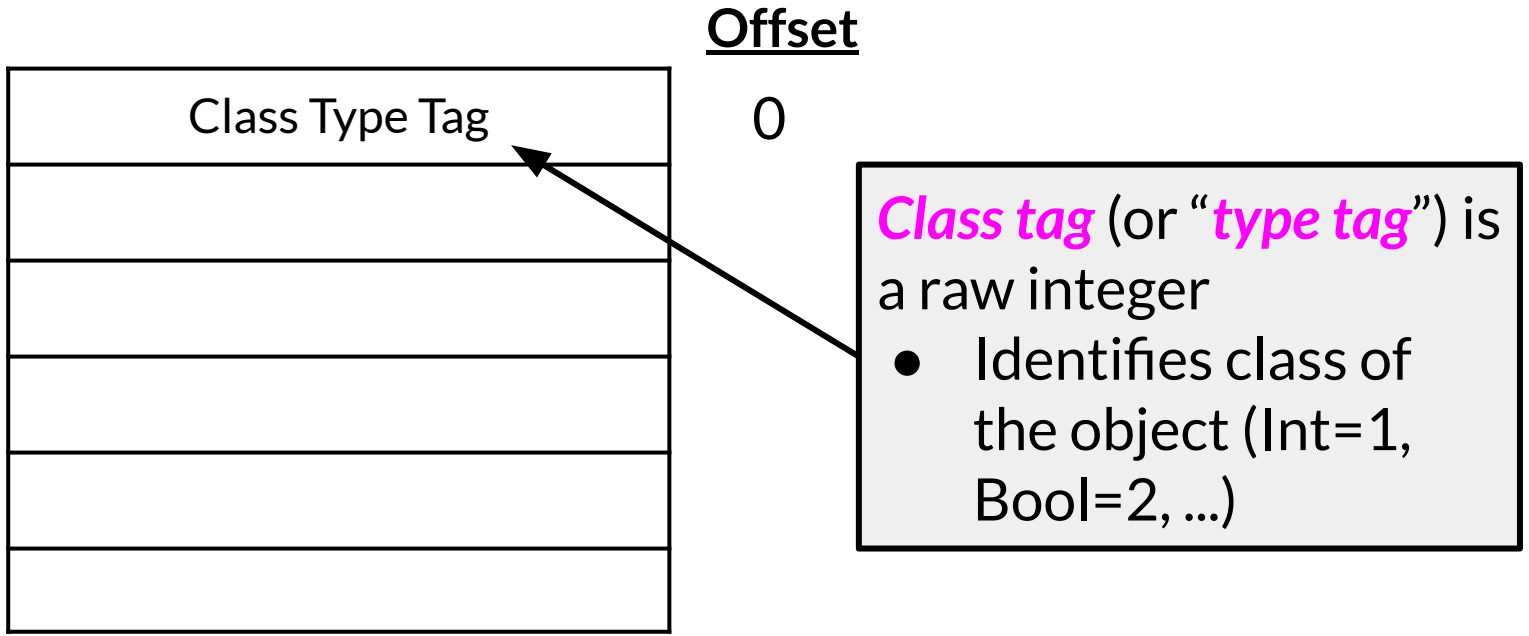

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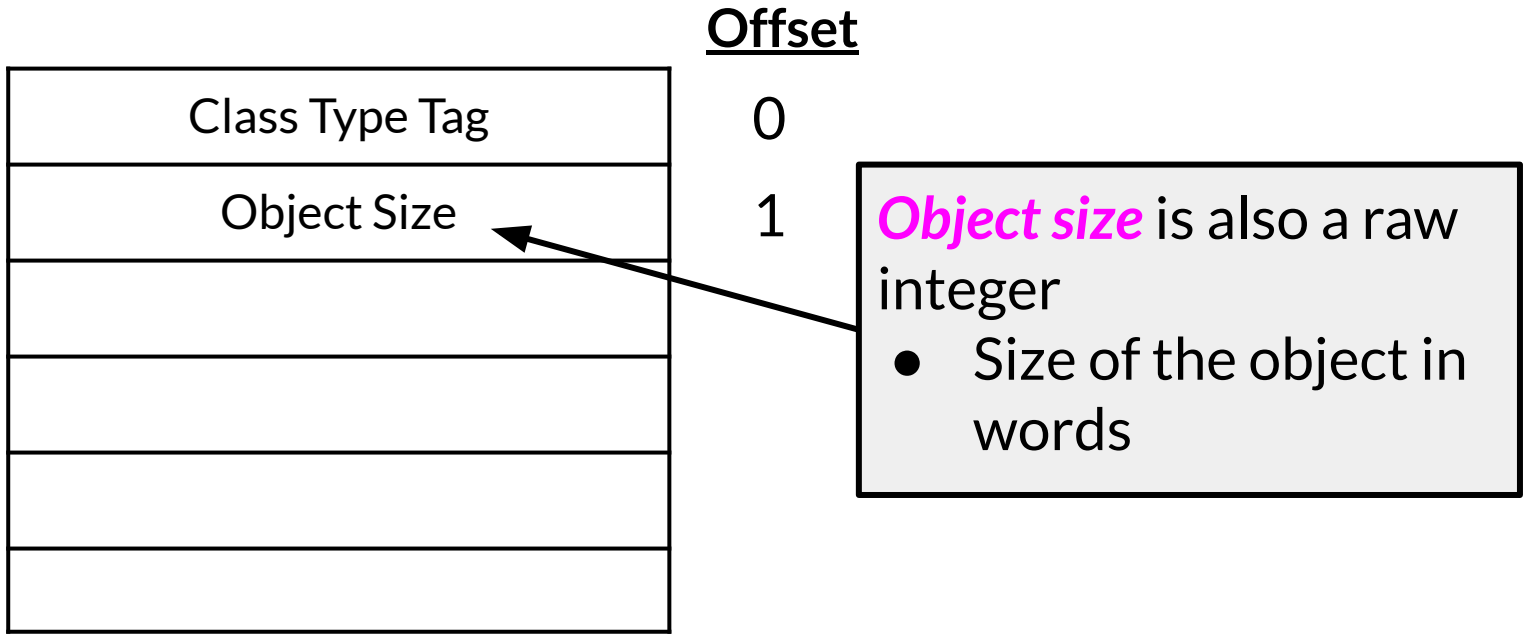

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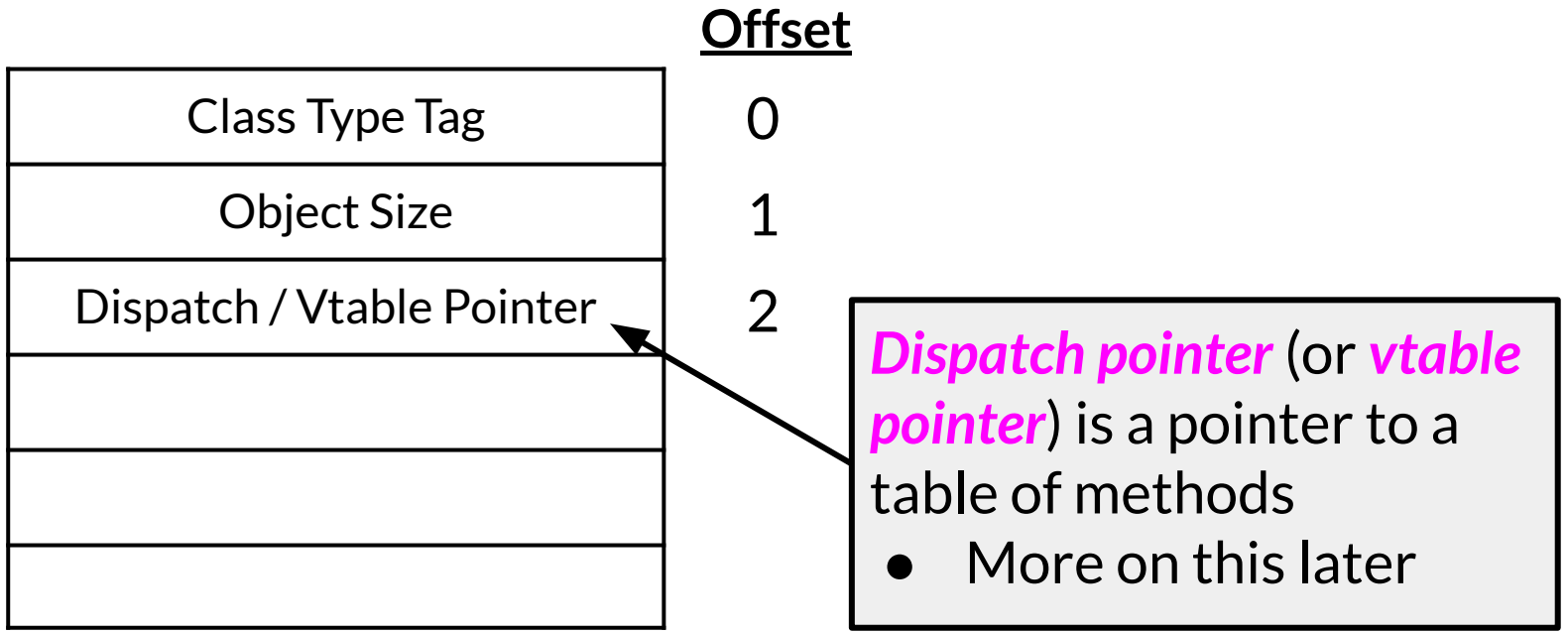

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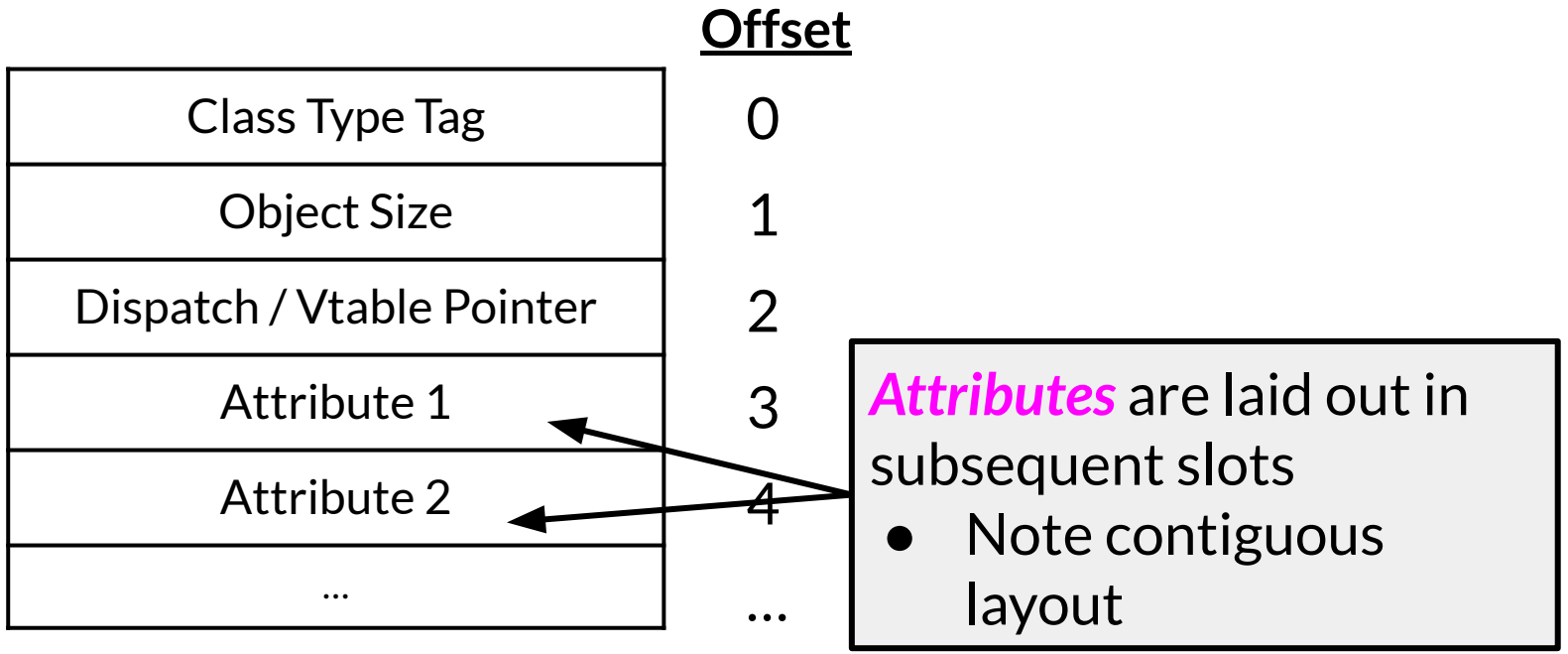

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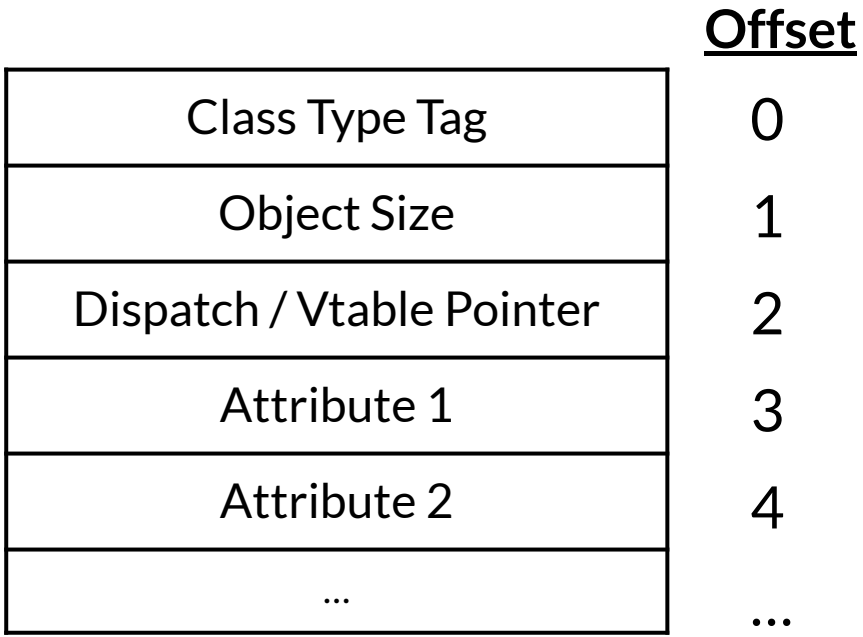

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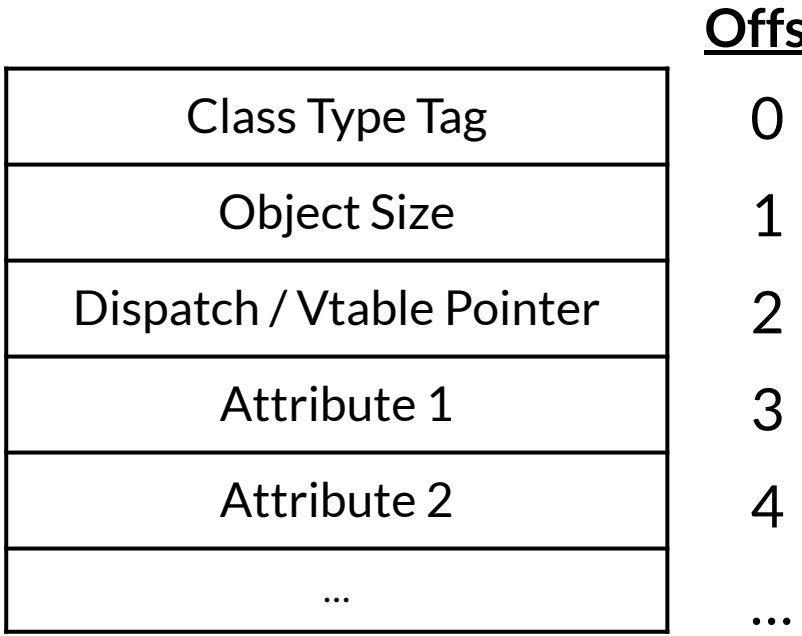

Note this is a convention that we made up, but it is similar to how Java and C++ lay things out. For example, you could swap #1 and #2 without loss.

Cool Object Layout: Example

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Things to note:

- Attributes **a** and **d** are inherited by classes B and C
- All methods in all classes refer to **a**
- For A methods to work correctly in A, B, and C objects, attribute **a** must be in the same “place” in each object

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  - (i.e., append new fields at the bottom)
  - leaves the layout of A **unchanged** (B is an extension)
  - this is where the “extends” keyword in Java etc comes from

Cool Object Layout: Example w/ Picture

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```

Class / Offset	A	B	C
0 (tag)	Atag	Btag	Ctag
1 (size)	5	6	6
2 (vtable)	*	*	*
3 (attr#1)	a	a	a
4 ...	d	d	d
5		b	c

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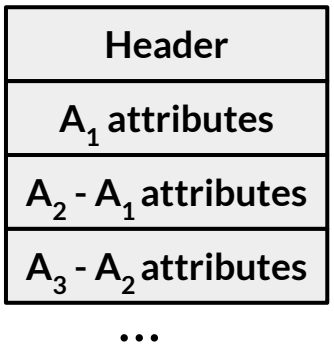

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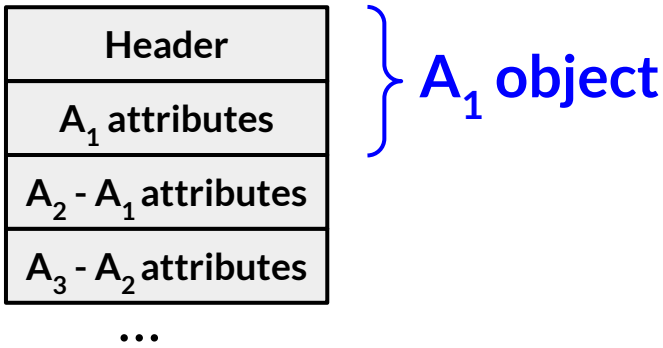

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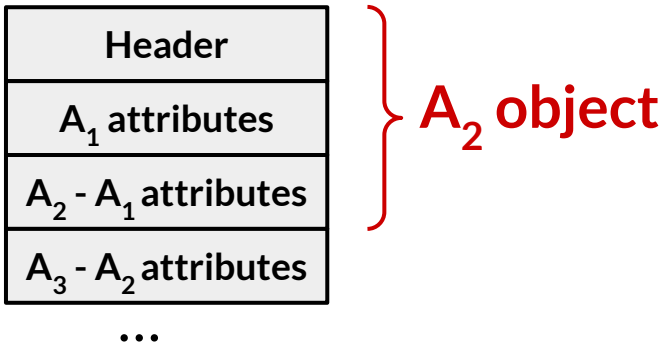

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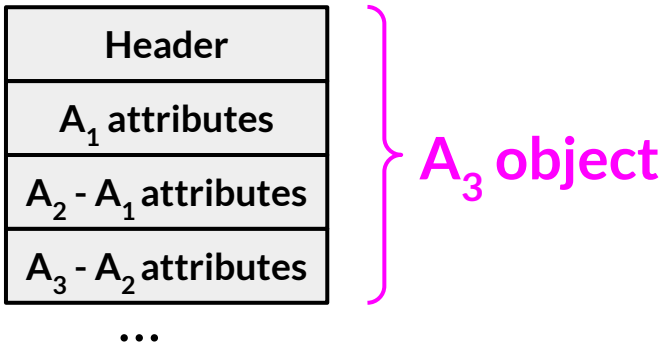

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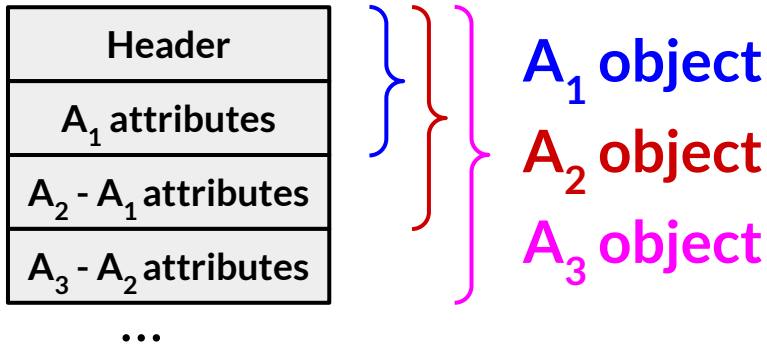

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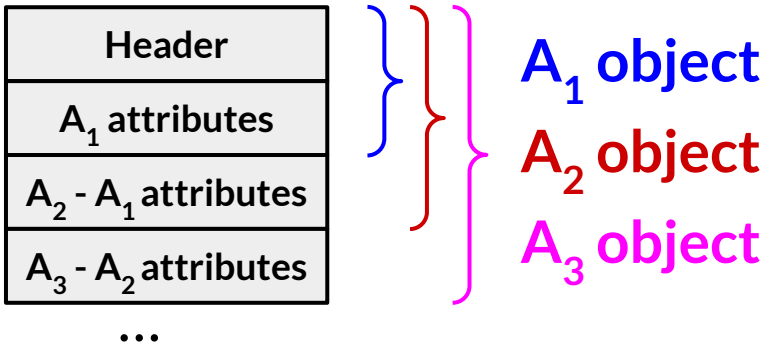

Challenge question: what about **multiple inheritance**, as in C++?

Cool Object Layout: Dynamic Dispatch

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```

Consider f() and g()

Cool Object Layout: Dynamic Dispatch

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Cool Object Layout: Dynamic Dispatch

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  - `f` refers to method in B for a B object

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- Consider `e.f()`
  - `f` refers to method in A if `f` is an A or C (inherited in the case of C)
  - `f` refers to method in B for a B object
- There is a correspondence here: the implementation of methods and dynamic dispatch **strongly resembles** the implementation of attributes

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  - A vtable is an array of method entry points
    - Thus, a vtable is an array of function pointers.
- A method f lives at a **fixed offset** in the dispatch table for a class **and all of its subclasses**
  - this works exactly the same way that attributes do

Cool Object Layout: Dispatch Table Example

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Class / Offset	A	B	C
0	f_A	f_B	f_A
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Cool Object Layout: Dispatch Table Example

- The dispatch table for class A has only 1 method
- The tables for B and C extend the table for A with more methods
- Because methods can be overridden, the method for f is not the same in every class, but is always at the same offset
  - (i.e., offset 0 here)

Class / Offset	A	B	C
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  - Call $D[O_f](x)$
    - `D` is the dispatch table for `x`
    - In the call, `self` is bound to `x` (why?)

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cgen(objexp)
bz r1 dispatch_on_void_error
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call temp
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call temp
pop fp
```

Course Announcements

- We recently fixed a bug in the reference compiler's x86-64 module. Only use Cool **version 1.39** for compiling to x86.
  - There will be an extra credit question on the midterm asking why I had to do this, if you want to do a comparison.
  - I will also award extra credit if you can find another bug in the reference compiler
- Don't forget there is a **midterm** in this class on Wednesday!
  - Review session: tonight at 5pm (virtually)
  - Extra office half-hours tomorrow at 10am, 4:30pm
- Hopefully you started PA3c3 over break
  - its due date is **one week from today**