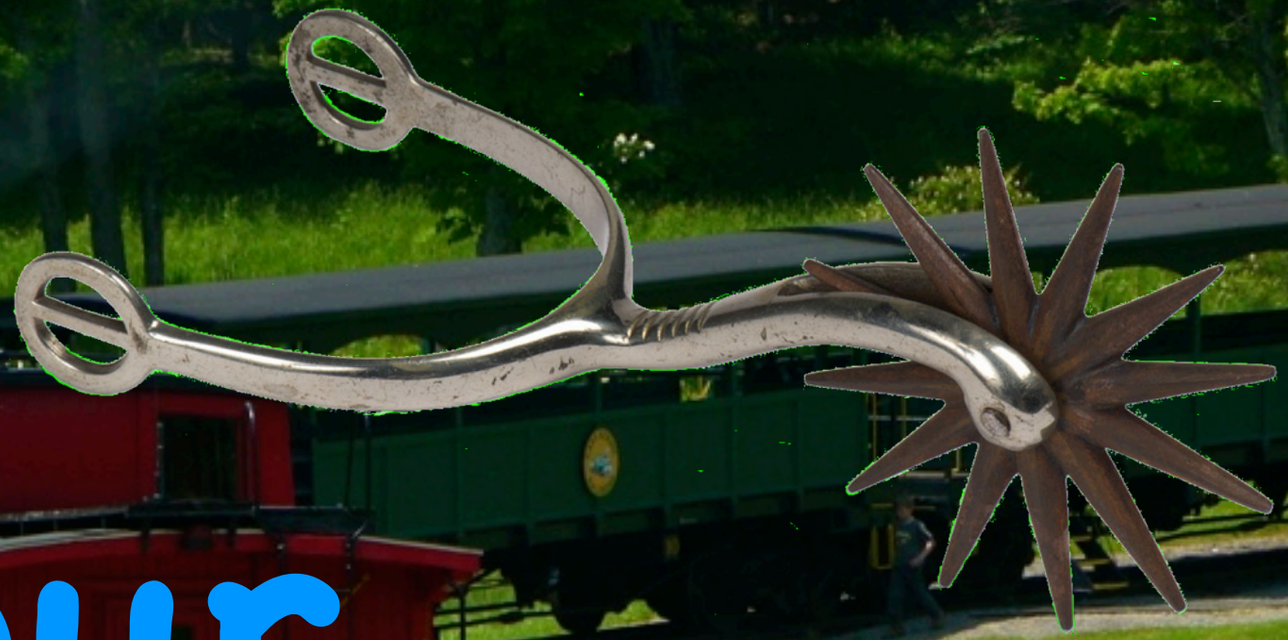
eliot@cadence.com

Spur

Confused images and mixed metaphors for Squeak Pharo and Newspeak



cadence®

Three Parts

VM Evolution

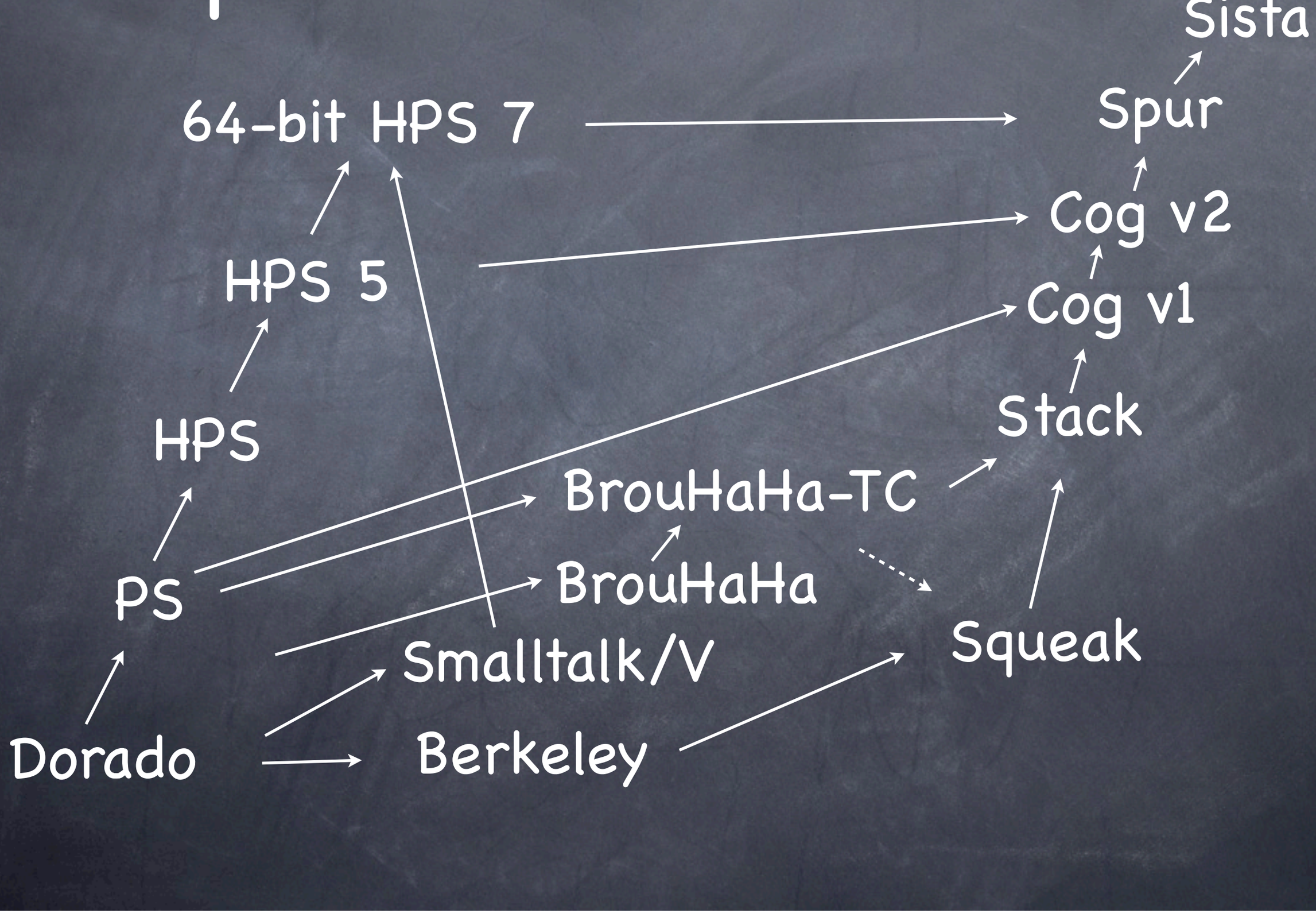
Lazy Forwarding/ Partial Read Barrier

Spur Memory Manager

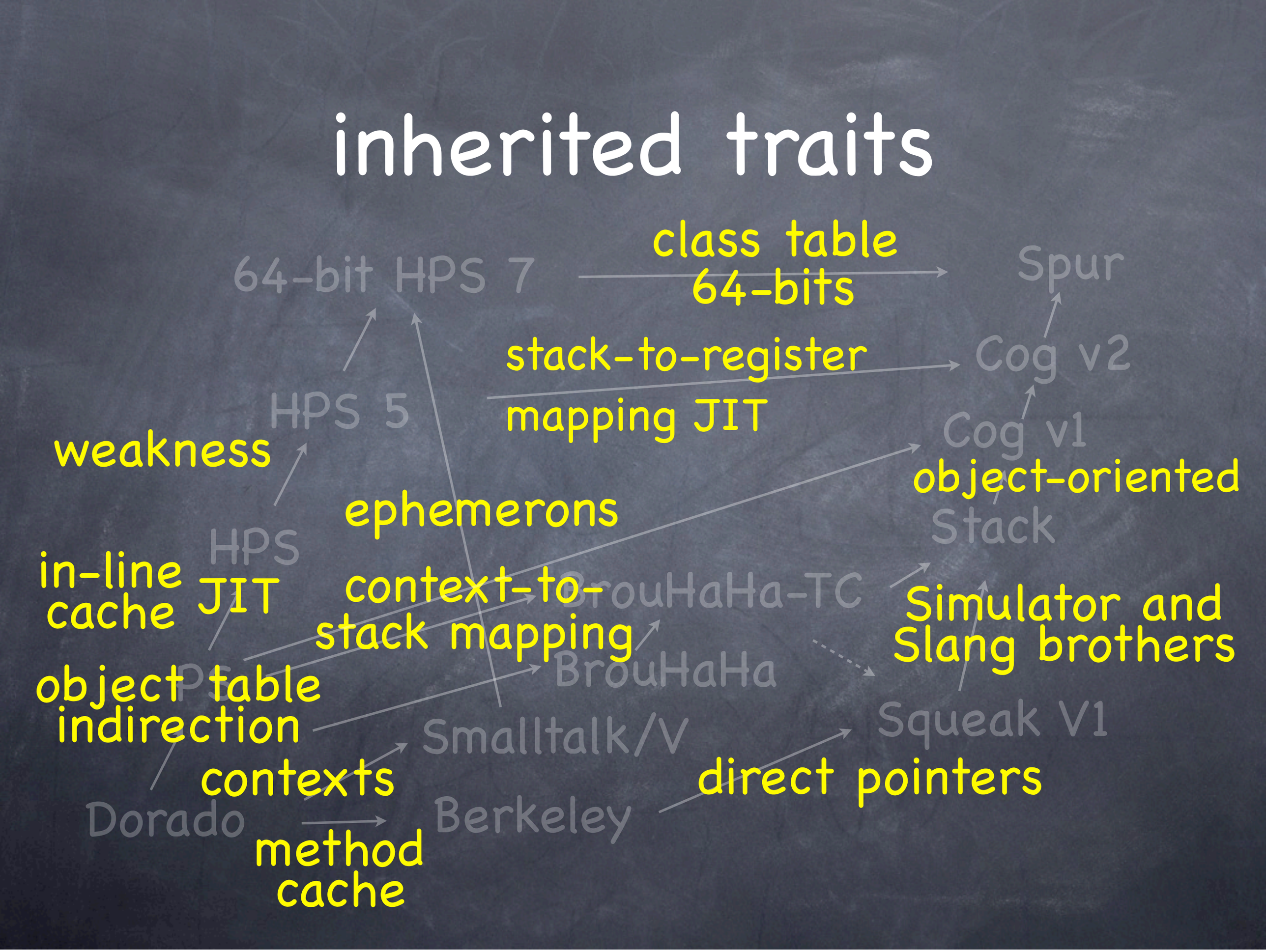
Spur isA: MemoryManager new

- faster
- more powerful
- 64-bit ready

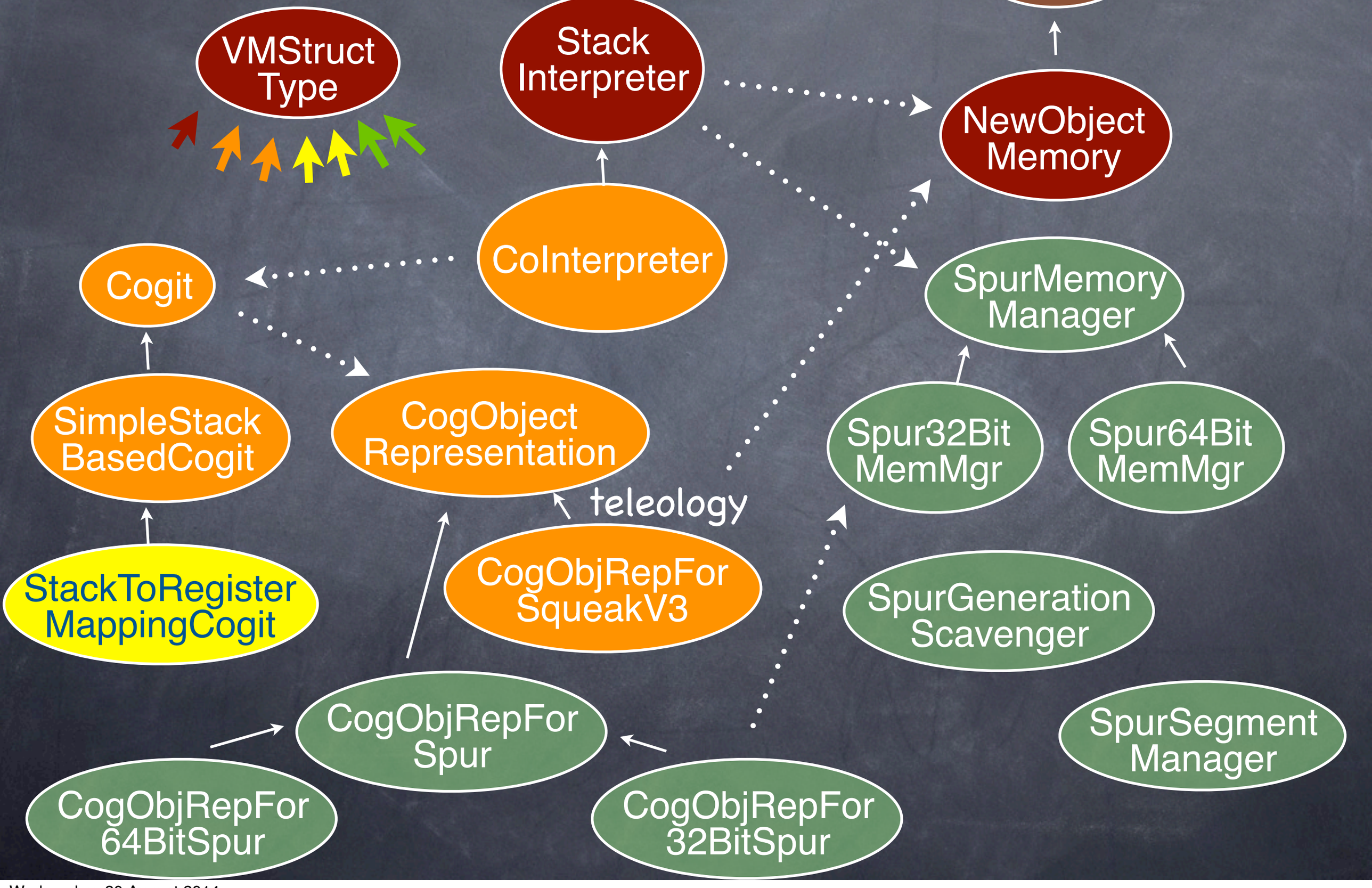
Spur isAn: Evolution



inherited traits

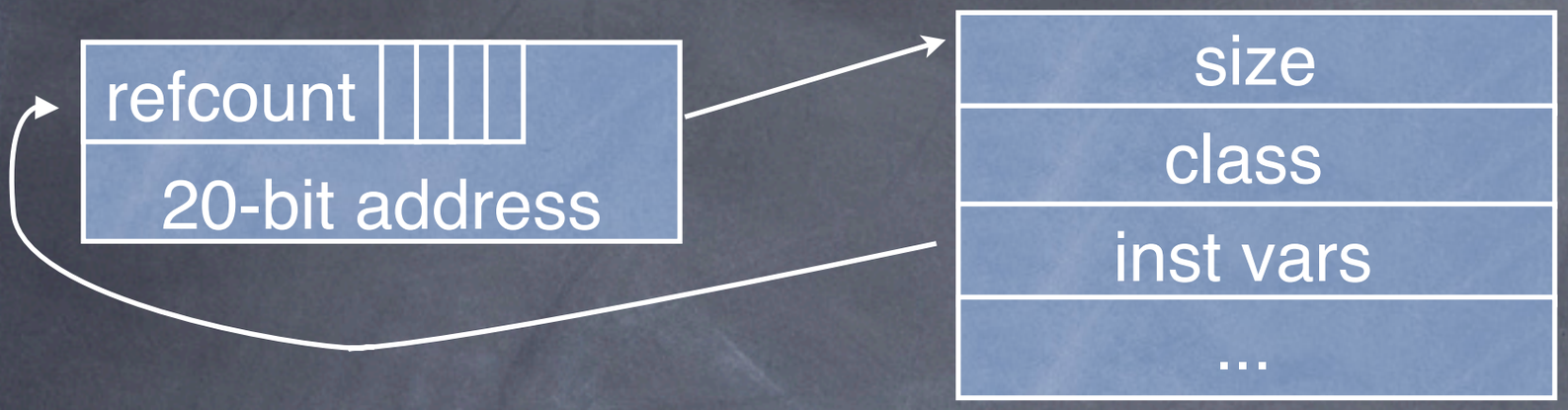


object-oriented??

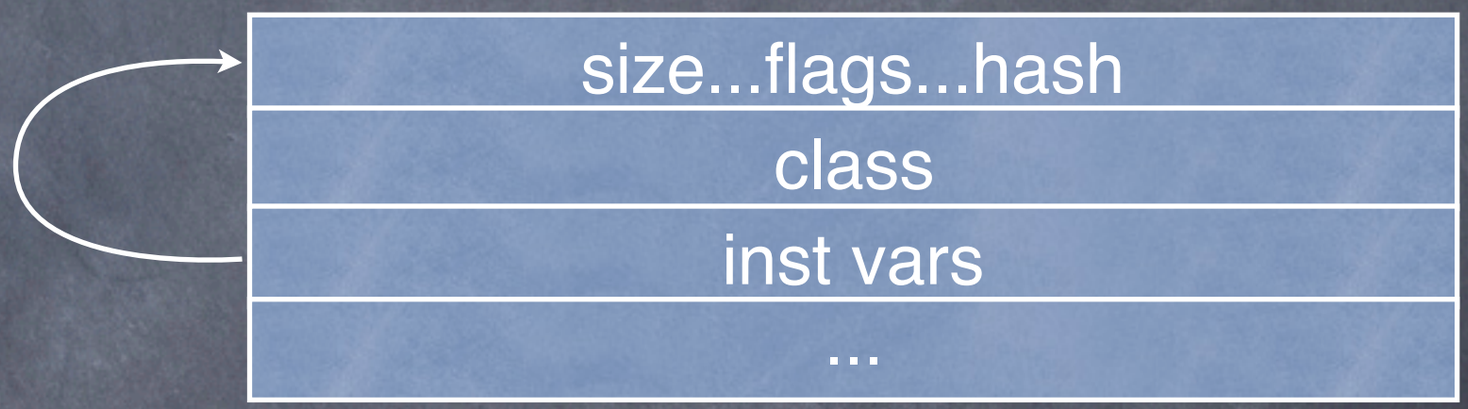


oops

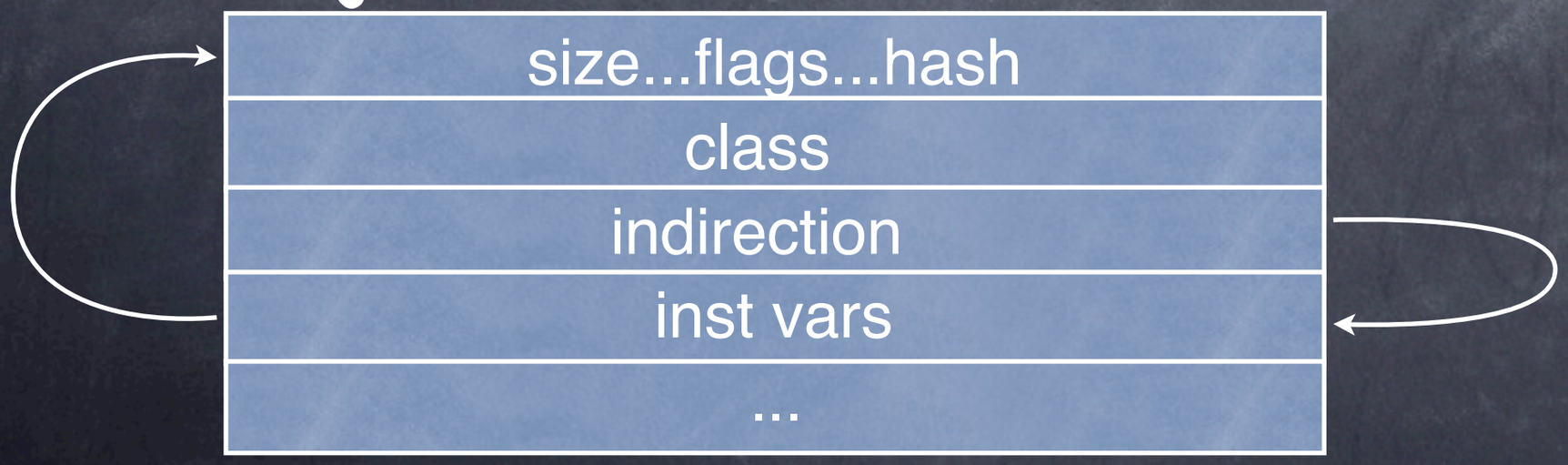
D-machine OTE



BS Direct Pointers

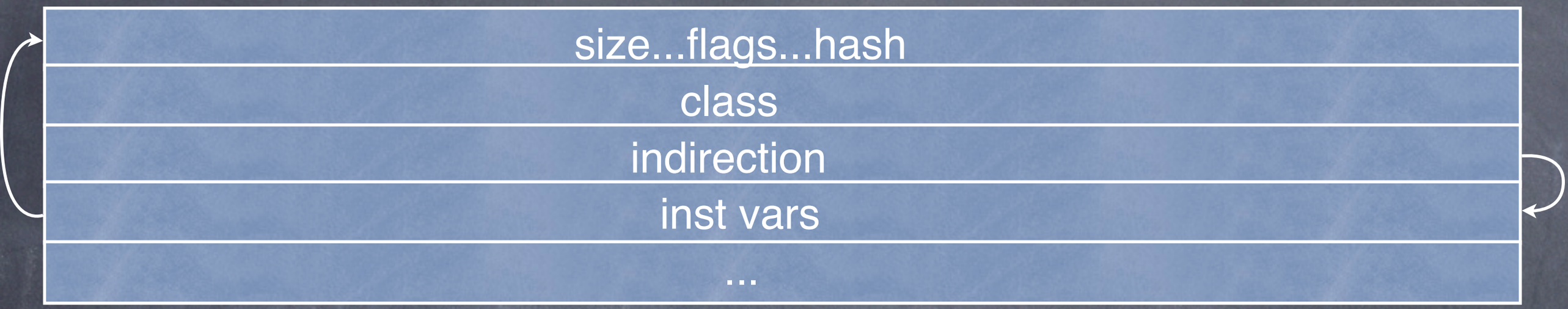


HPS Object Table Indirection

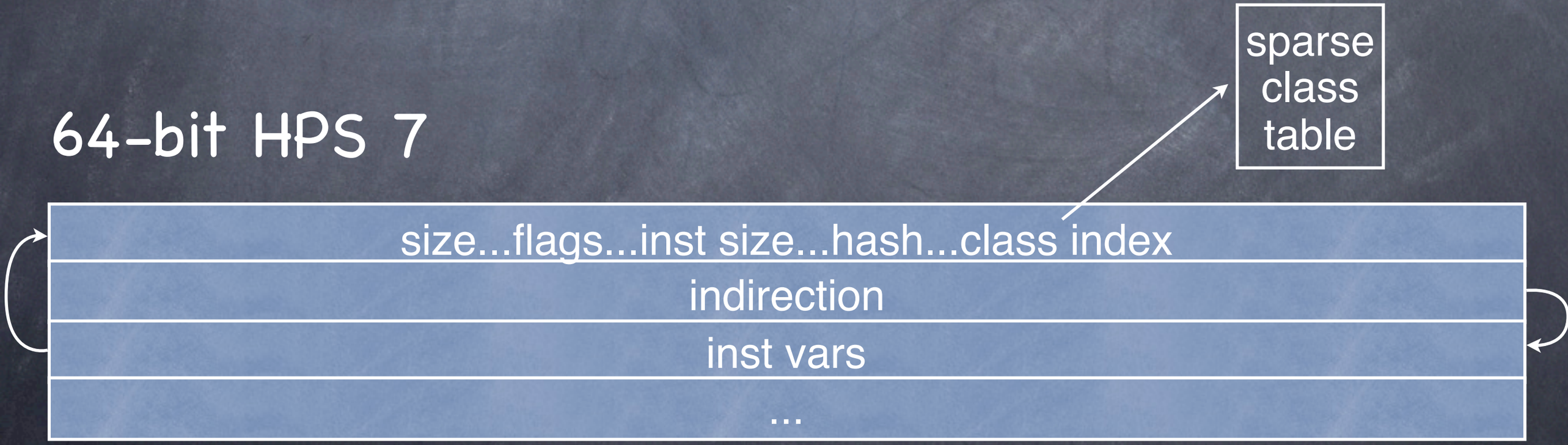


oops!

yeah, right...



64-bit HPS 7



class indices/class tags

- class index is index of class in class table
- class's identity hash is its index in class table

  ∴ its instances' class tag
  Behavior>>identityHash (& Behavior>>new)
- use them in method caches; resolve to class object on #class or full method lookup
- constants, never moved by GC
- cheap allocation of well-known objects
- puns & special non-objects

evolution

- top-down selection pressure (≈tests)

- bottom-up refinement (≈ pink plane)
- exaptation (≈ blue plane)

possible aquatic adaptations in human — *species :* ***Homo sapiens***

arguments for the ***aquatic ape hypothesis*** *and related* ***water-based models*** — *proposed natural habitat :* ***coasts & beaches***

swimming & floating

- human is **the best swimmer** & **diver** among the apes, capability lasts **from birth to death**
- various **swimming gaits** like breaststroke, front crawl...

dark skin pigment blocks sunlight in tropical waters ③

reduced body hair & **smooth skin surface** reduce drag ①

subcutaneous fat layer
- prevents heat loss
- increases buoyancy
- streamlines the body ① ②

fusiform, straight, streamlined body reduces drag ①

rare condition of **webbed toes** ②

force exerted on **the first** & **the last toes** (like in seals) ③

paddle-like feet with fused toes for both water & land locomotion ③

water birth the natural way of laboring in human
- less painful, low risk
- preferred by women
- infant mortality & infection rates no higher than land births
- practiced in primitive cultures ③

infant are able to swim/dive **before** being able to crawl/walk, **no fear or harm** caused by immersion ②

> 1 year voluntary movements, starts **learning** to swim, dive, walk... ③

4-12 months **infant floating reflex**: rolls onto the back to float & breathe ③

0-4 months **infant diving reflex**: opens eyes, holds breath, rhythmic limb movements to propel forward ③

scooper-like hands with thumb webbing for catching water ②

flexible arms & **shoulders** produce steering strokes ②

rare condition of **webbed fingers** ②

hair growth pattern follows water flow ①

lower normal body temperature with **low fluctuations** like in aquatic mammals ①

long legs produce powerful propelling force in swimming, diving & running ②

brown fat tissues generates heat ①

abundant body fat prevents heat loss & increases buoyancy ②

multi-lobed kidney (reniculi) as in marine mammals (fused later) ①

vernix caseosa (waxy substance with **squalene** on newborns) with waterproofing & antibacterial properties ④②

newborn **holds breath** until reaching water surface ③

no practice of eating placenta (placentophagy) as not possible in water ①

pregnancy & infancy

immersion relieves pain, reduces stress hormones (**adrenaline**) & facilitates "love" hormone (**oxytocin**) ②

large floating breasts help feeding while immersed ①

gender & sex

longer scalp hair (becomes **thicker** & **stronger** during pregnancy) for the floating infant to cling on ②

facial hair & **bald head** streamlines the head and neck for diving ③ *or* **facial hair** as a sexual signal above water surface

protruding buttocks (in extreme case **steatopygia**) as a platform for carrying baby ③

longer penis in response to deeper vagina ④

longer vaginal canal isolates the uterus from sea water ④

menstruation synchronized with circalunar (tidal) cycle ④

labia major, hymen & **vaginal ridges** waterproof the vagina, **low pH** ~4.5 & **lactobacillus colony** in vaginal canal inhibit waterborne pathogens ④③

hidden estrus due to visual signals (genital swelling) & scent signals (pheromone) not efficient in water ④

more **face-to-face sex** due to straight body plan, vagina directed towards the front ②

walking & running

bipedalism may be enhanced by **wading**
- for shallow water foraging
- supported by water buoyancy
- overcame various disadvantages ①③

obligatory bipedalism & **upright posture** due to straight body plan & long legs (diving) ②

endurance running only **recently evolved**
- pre-adaptations: strong legs, good balancing...
- new adaptations: eccrine sweating, foot arches, short toes... ③

inherited from ape ancestors:
- climbing, gymnastics
- partial bipedalism & partial upright posture
- opposable thumb

diving & foraging

- **underwater foraging** important to early *Homo sapiens*, still practicing among coastal tribes
- **collecting shellfish** & **hunting fish** for food, precious **shells** & **pearls** for trading
- **bimodal diving pattern** similar to sea otters (serial short dives to <20m, separated by recovery intervals, in extreme cases **dive to 100m**) ①

fewer & larger red blood cells, higher concentration of **hemoglobin** ①

spleen contracts to release extra red blood cells ②

able to **equalize ears** at depth ①

descended larynx allows mouth breathing for inhaling more air before dives / during swim ③

better **voluntary breath control** for planning of inhalation ②

breathing pattern (quick inhale & slow exhale) similar to speech ③

fine breath control pre-adapted for **speech**

flexible backbone allows lift-based "dolphin kick" under water ②

dexterous, sensitive hands for collecting & hunting, started **tool-making** on the shore ①

enhanced **diving reflexes**

bradycardia: heartbeat reduces during immersion ②

peripheral vasoconstriction: blood flow to limbs cuts down to save oxygen for important organs ①

blood shift: blood fills lung vessels & cavities in extreme depth to prevent organs crushed ①

multi-pyramidal kidneys excrete salt from sea water ①

high output of water & salt: abundant sweat & tears, saturated expiration, dilute urine, watery faeces ①

sweat (perhaps also **tears**) excretes excess salt ②

head & upper body

- **waterproofing** & **thermoregulation** in the head & upper body – usually out of water; **insulation** in the lower parts
- **oral cavity modified** for aquatic diet, later enabled **speech**
- **brain enlargement** enabled by marine diet
- **senses attuned** to aquatic environment

scalp hair blocks sunlight in the tropical waters ①

greasy hair for waterproofing ③

recent brain shrinkage due to change to riverine & terrestrial habitat ②

enlarged semicircular canals give better balance under water & on land (bipedalism) ②

myopia & **astigmatism** correct for light refraction in water ③

good **underwater vision** by maximally constricting pupils ①

color vision & **color blindness** adapted to aquatic environment ①

brain enlargement enabled by **marine diet** (seafood, seaweed)
- high availability & reliability
- essential **micronutrients** (DHA, iodine, zinc, selenium...) ①

brain enlargement & reorganization led to **higher intelligence, creativity** & **syntactic ability** ②

syntax + speech/song = human language

speech, song & **facial expressions** replaced body expressions as more efficient above water surface ②

vocal learning, **speech** & **song** enabled by
- fine breath control (for diving)
- enhanced articulating apparatus (for aquatic diet) ①

ear wax (contains sebum) repels water entering the ears ③

paranasal sinuses assist the head floats above water surface ③

downward nostrils avoid water splashes in ②

upper lip & **philtrum** enable sealing of nostrils while diving ④①

- **specialized oral cavity** (small mouth, round jaw & palate, reduced teeth, round versatile tongue) for **suction feeding** of slippery seafood, pre-adapted for **speech**
- **blunter molars** with **thick enamel** for cracking hard shellfish ①

low drinking capacity, low tolerance to **dehydration** ③

vestigial air sacs (laryngeal saccule) used to aid floating in ape ancestors ①

sebaceous glands secret **sebum** (with **squalene**) for waterproofing (in head, upper body, back) ③

sweat evaporates through the upper body (highest rate in head, upper body, back) ②

reduced smelling sense as useless in or above water ②

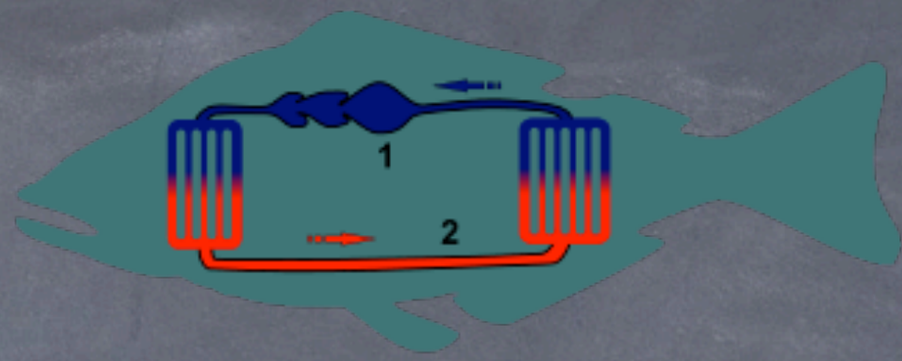
no salt hunger & **high tolerance in salty taste** since salt is everywhere in the sea ③

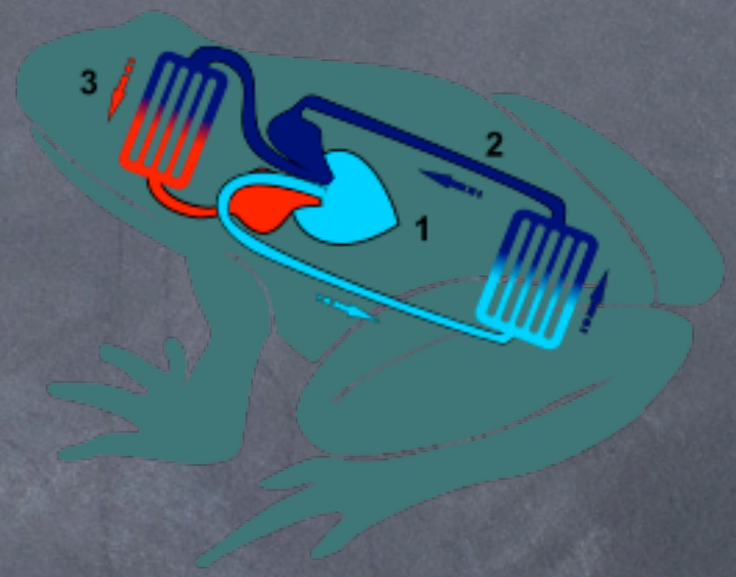
References: ❶ Hardy AC (1960) Was man more aquatic in the past? *New Scientist* 17 Mar 7 (174): 642-645 ❷ Morgan E (1982) *The Aquatic Ape*. Stein & Day Pub ❸ Morgan E (1990) *The Scars of Evolution*. Souvenir Press ❹ Morgan E (1997) *The Aquatic Ape Hypothesis*. Penguin ❺ Roede M, Wind J, Patrick J, Reynolds V (eds.) (1991) *Aquatic Ape: Fact or Fiction?* Souvenir Press ❻ Vaneechoutte M, Kuliukas AV, Verhaegen M (eds.) (2011) *Was Man More Aquatic in the Past? Fifty Years After Alister Hardy - Waterside Hypothesis of Human Evolution*. Bentham Science Publishers ❼ Cunnane SC, Stewart KM (eds.) (2010) *Human Brain Evolution: The Influence of Freshwater and Marine Food Resources*. Wiley-Blackwell ❽ Niemitz C (2010) The evolution of the upright posture and gait – a review and a new synthesis. *Die Naturwissenschaften* 97 (3): 241-263 ❾ Odent M (1996) *We are All Water Babies*. Celestial Arts ❿ Verhaegen M et al.: various publications in *Medical Hypotheses* (1985, 1987), *Nutrition and Health* (1993), *Ecology Research Progress* (2007)

Aquatic Ape Hypothesis

Wednesday, 20 August 2014

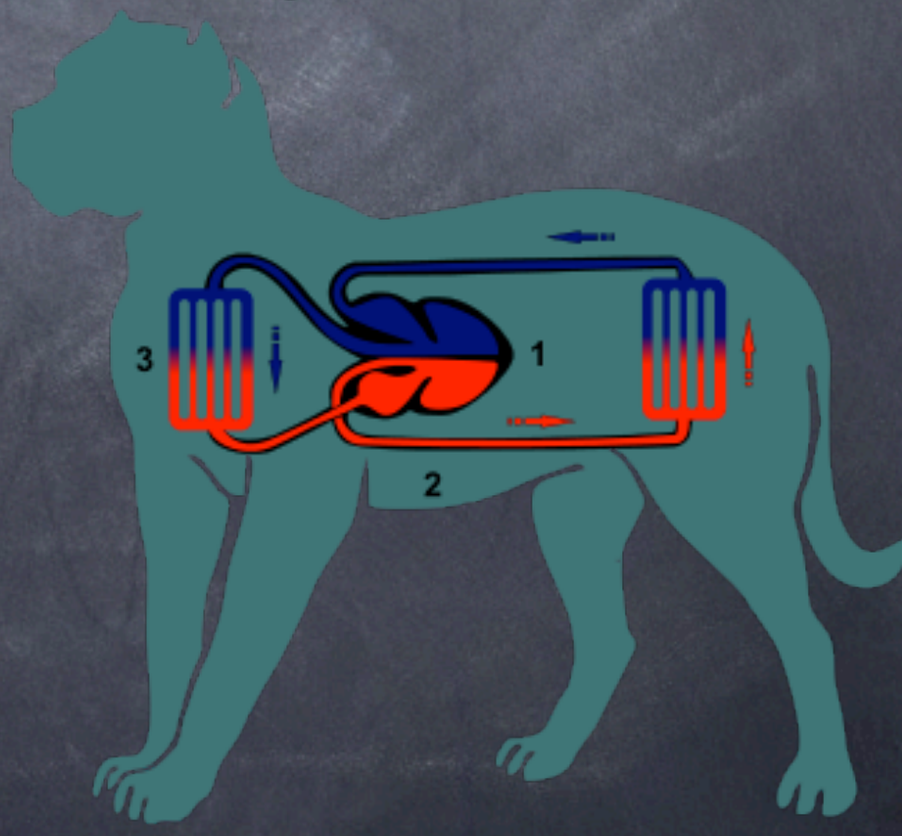
The VM System



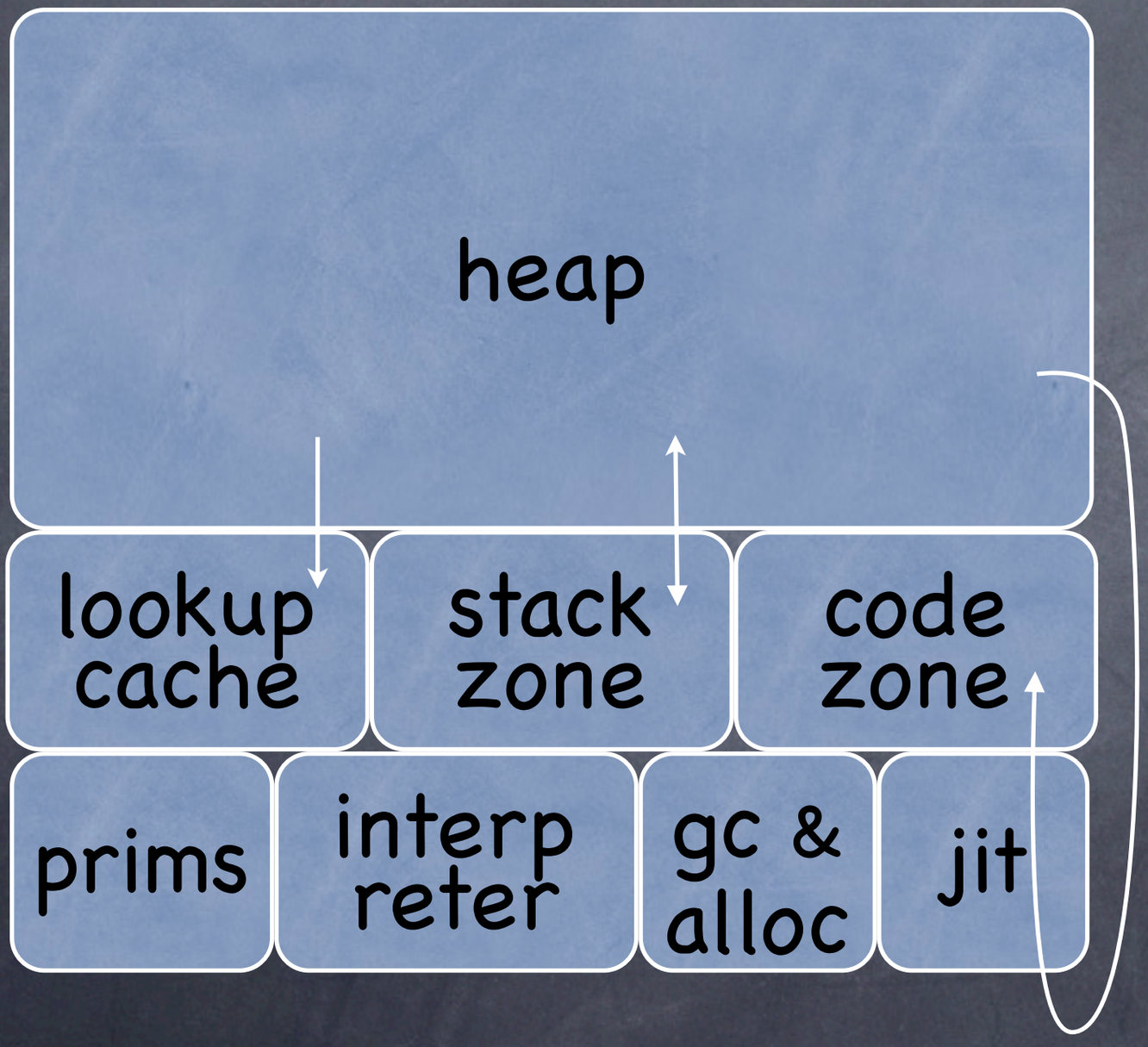


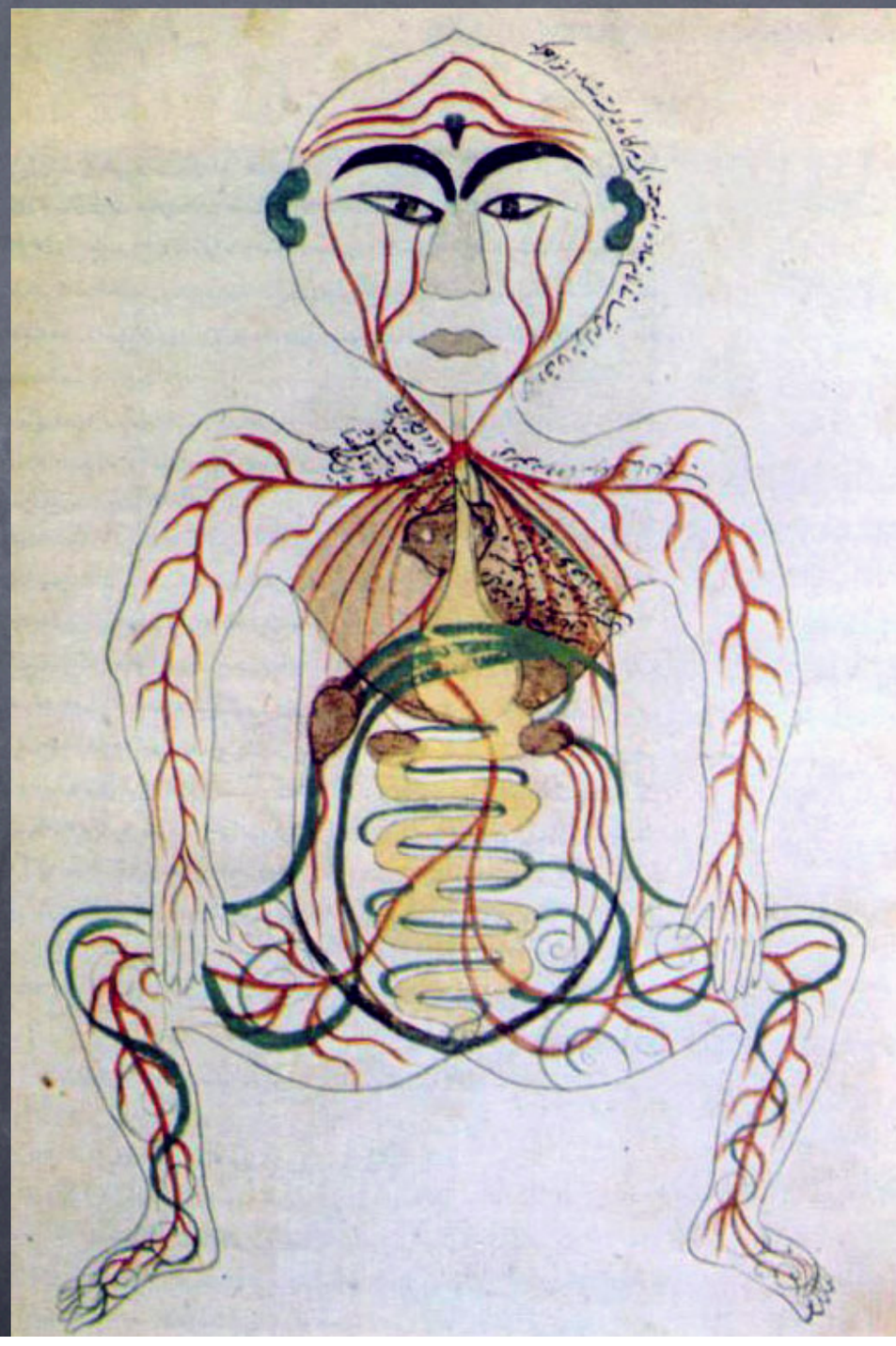
heap

prims | interp reter | lookup cache | gc & alloc



The VM System





method lookup

```
findNewMethod
    "Find the compiled method to be run when the current
     messageSelector is sent to the class lkupClass, setting
     the values of newMethod and primitiveIndex."
    <inline: true>
    | ok |
    ok := self lookupInMethodCacheSel: messageSelector class: lkupClass.
    ok ifFalse: "entry was not found in the cache; look it up the hard way"
        [self lookupMethodInClass: lkupClass.
         self addNewMethodToCache]
```

Exapt

- method cache probe
- class tags
- stack zone
- primitives

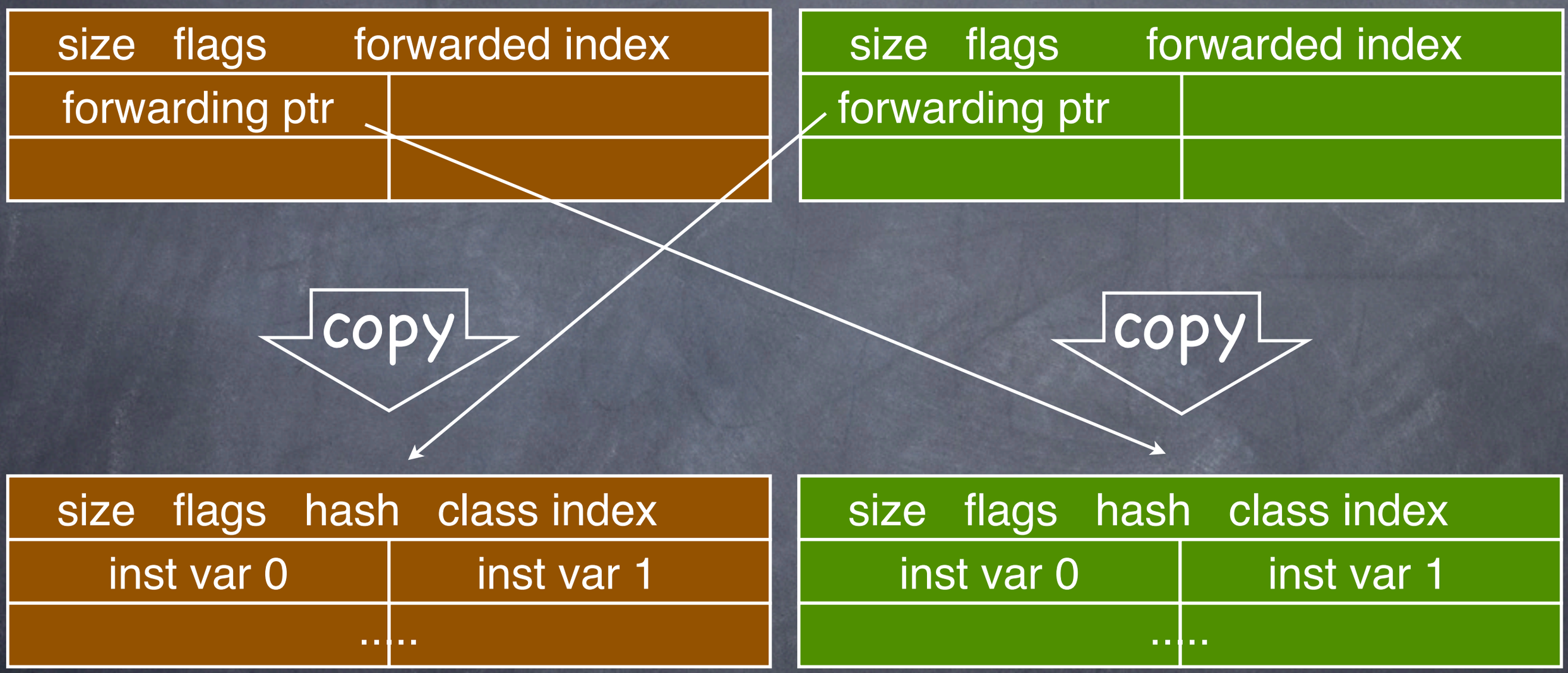
Exaptation

- become lazy
- all objects can be forwarders
- forwarded class tag fails method cache probe
- follow on message lookup
- stack zone scan avoids inst var access read barrier

become


size flags hash class index
inst var 0
inst var 1
.....
size flags hash class index
inst var 0
inst var 1
.....

become


size flags forwarded index
forwarding ptr
size flags forwarded index
forwarding ptr
copy
copy
size flags hash class index
inst var 0
inst var 1
.....
size flags hash class index
inst var 0
inst var 1
.....

follow

```
followForwarded: objOop
    | referent |
    referent := self fetchPointer: 0 ofMaybeForwardedObject: objOop.
    [(self isOopForwarded: referent)] whileTrue:
        [referent := self fetchPointer: 0 ofMaybeForwardedObject: referent].
    ^referent
```

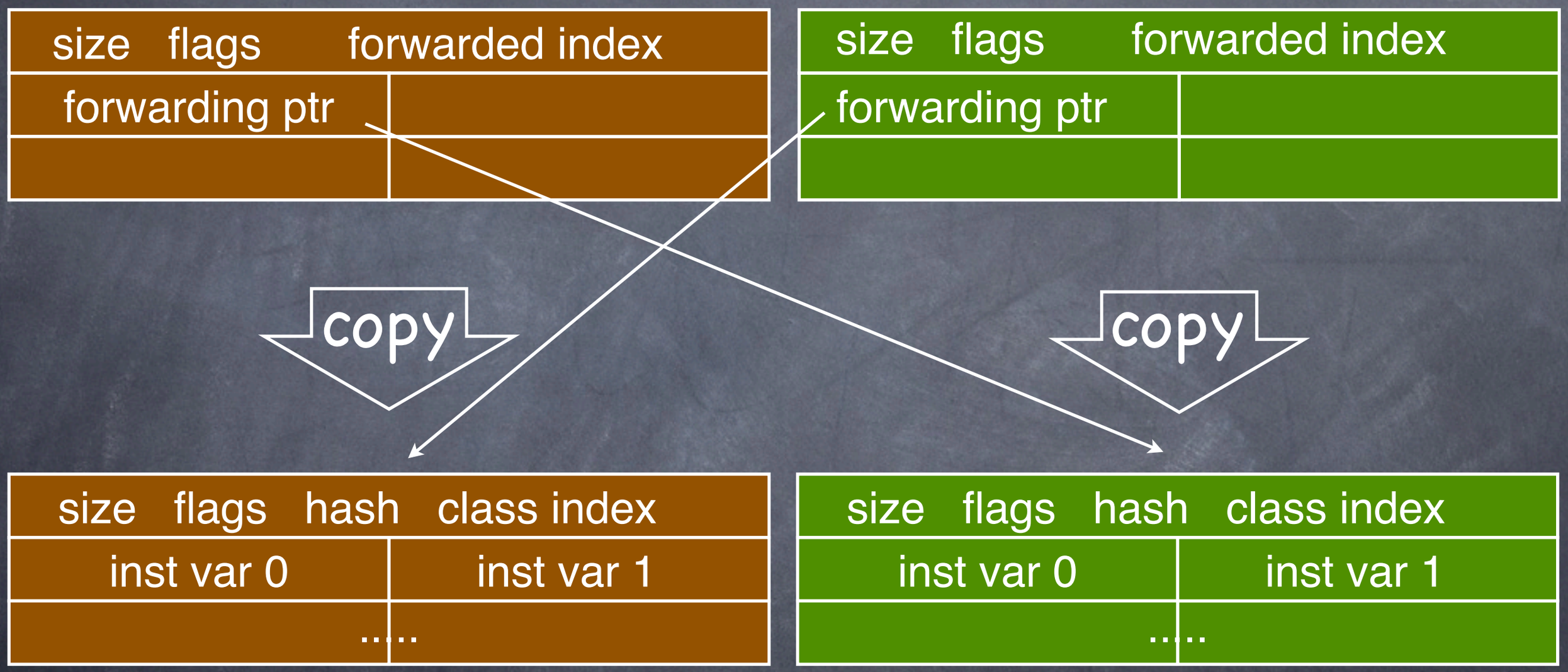
```
followField: fieldIndex ofObject: anObject
    | objOop |
    objOop := self fetchPointer: fieldIndex ofObject: anObject.
    (self isOopForwarded: objOop) ifTrue:
        [objOop := self followForwarded: objOop.
         self storePointer: fieldIndex ofObject: anObject withValue: objOop].
    ^objOop

ObjectMemory>>followField: fieldIndex ofObject: anObject
    ^self fetchPointer: fieldIndex ofObject: anObject
```

lazy forwarding issues

- inst var access
  (& method access in interpreter)
- message sends
- class hierarchy method lookup
- global var access (including super sends)
- primitives

lazy forwarding: inst vars partial read barrier



+ if became pointer or method object,
scan stack zone to follow forwarding pointers

lazy forwarding: sends

```
findNewMethod
    (self lookupInMethodCacheSel: selector classTag: lkupClassTag) ifFalse:
        [((heap isOopForwarded: selector)
            or: [heap isForwardedClassTag: lkupClassTag]) ifTrue:
             [(heap isOopForwarded: selector) ifTrue:
                [selector := self handleForwardedSelectorFault: selector].
              (heap isForwardedClassTag: lkupClassTag) ifTrue:
                [lkupClassTag := self handleForwardedTagFault: lkupClassTag].
             (self lookupInMethodCacheSel: selector classTag: lkupClassTag)
                ifTrue: [^self]].
    lkupClass := heap classForClassTag: lkupClassTag.
    self lookupMethodInClass: lkupClass.
    self addNewMethodToCache: lkupClass]
```

lazy forwarding: class hierarchy method lookup

- after any pointer become could scan
  every class in class table
  every method on entry to stack zone
  - KISS
    read barrier on access

superclassOf: classObj
"Read barrier here costs very little because lookup is rare,
& class and superclass almost certainly share a cache line."
^objectMemory followField: SuperclassIndex ofObject: classObj

lazy forwarding: global variable access

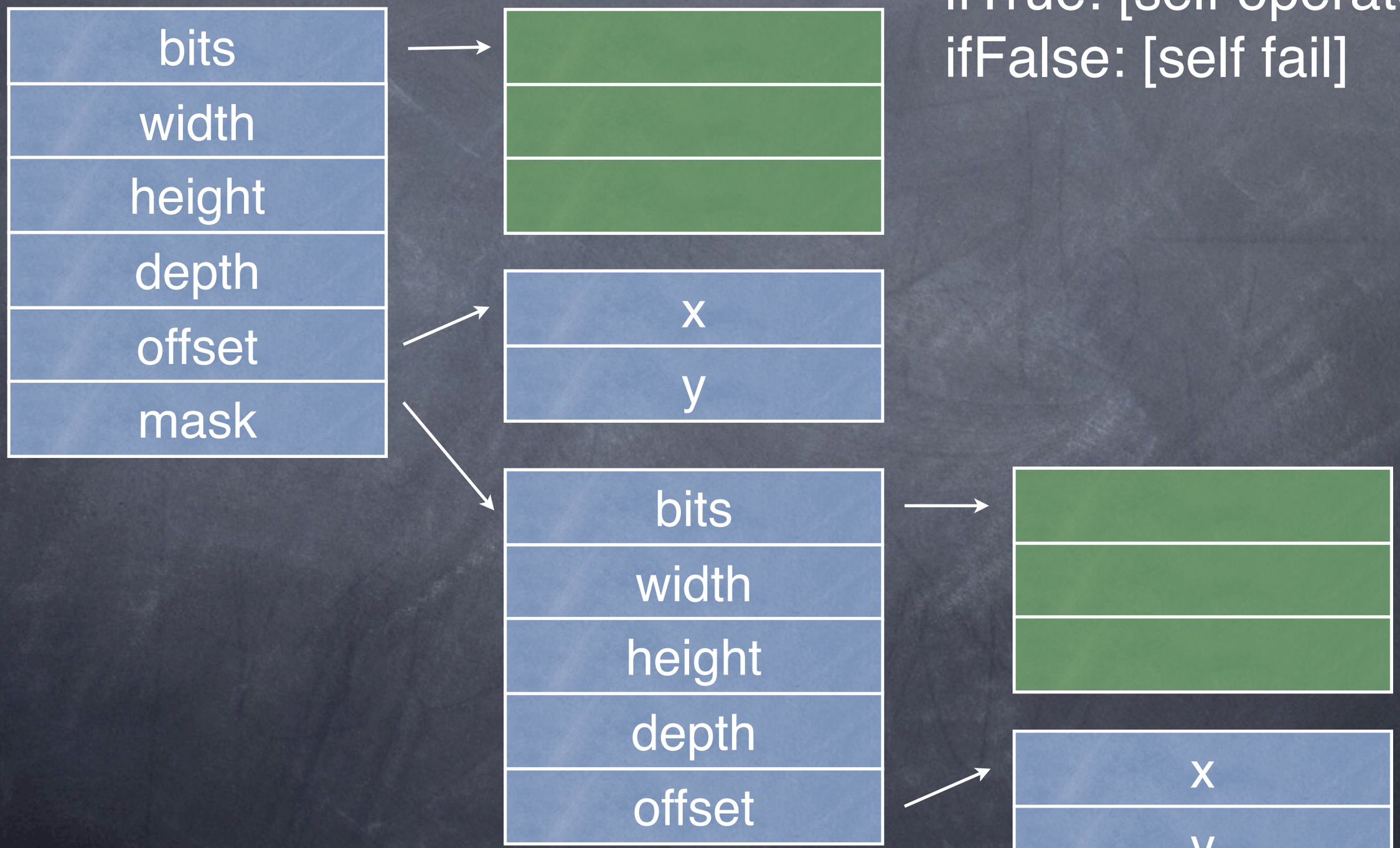
- after any pointer or method become could scan
  every method in stack & code zones
  every method on entry to stack zone

- KISS
  - read barrier on access

```
pushLiteralVariable: literalIndex
    | litVar |
    litVar := self literal: literalIndex.
    (heap isForwarded: litVar) ifTrue:
        [litVar := heap followForwarded: litVar].
    self push: (heap fetchPointer: ValueIndex ofObject: litVar)
```

lazy forwarding: primitives

```
self validate
    ifTrue: [self operate]
    ifFalse: [self fail]
```



primitives

```
self validate
    ifTrue: [self operate]
    ifFalse: [self fail]
```

```
slowPrimitiveResponse
    primFailCode := 0.
    self perform: primitiveFunctionPointer.
    self successful ifFalse:
        [self checkForAndFollowForwardedPrimitiveState ifTrue:
            [primFailCode := 0.
            self perform: primitiveFunctionPointer]]

checkForAndFollowForwardedPrimitiveState
    | depth |
    depth := primitiveAccessorDepths at:
                    (self primitveIndexOf: newMethod).
    ^accessorDepth >= 0
      and: [self followStackedArgumentsToDepth: accessorDepth]
```

Spur Memory Manager

- ephemerons
- object representation & heap walking
- pig compaction
- pinning, bridges and segments
- debugging

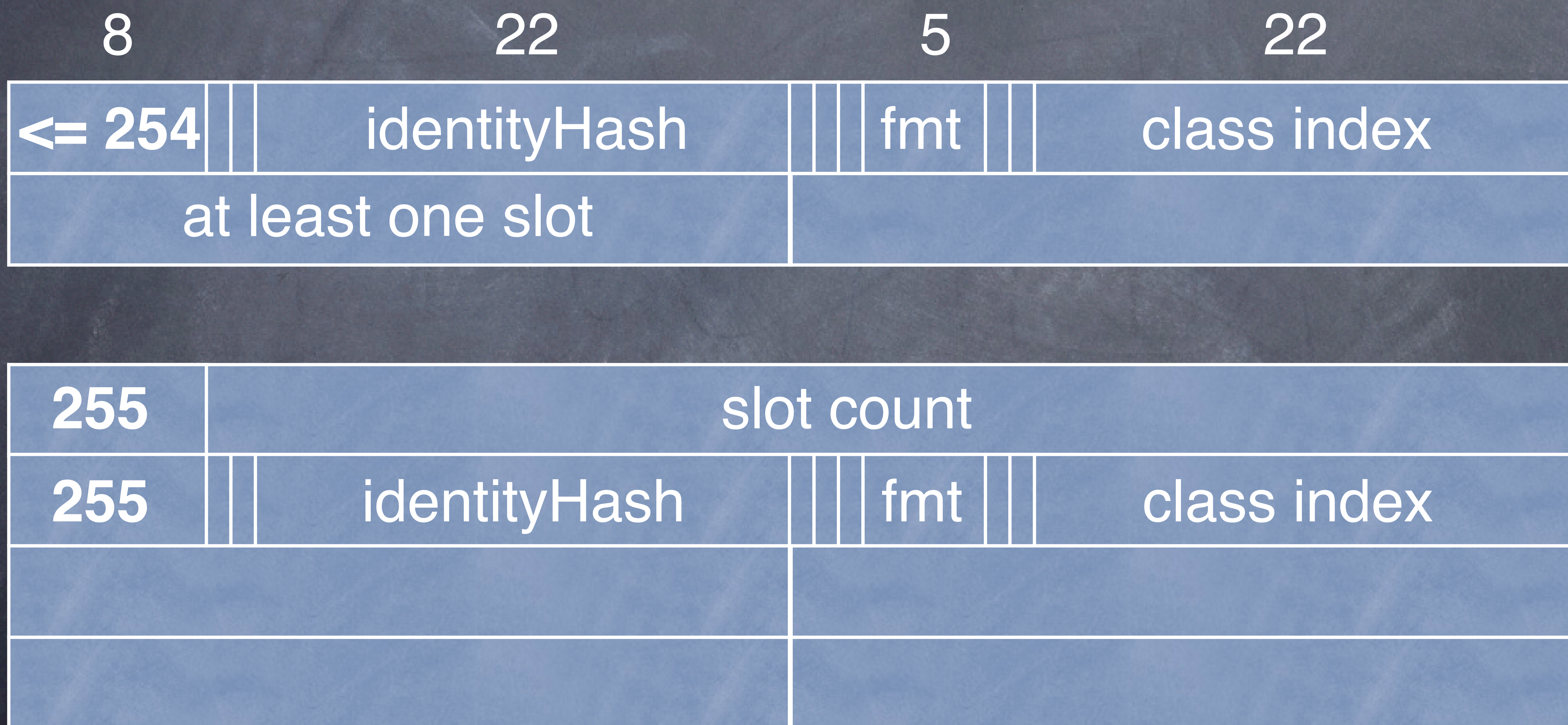
ephemerons

processEphemerons

"There are ephemerons to be scavenged. Scavenge them and fire any whose keys are still in pastSpace and/or eden. The unscavenged ephemerons in this cycle can only be fired if all the unscavenged ephemerons in this cycle are firable, because references to ephemeron keys from unfired ephemerons should prevent the ephemerons with those keys from firing. So scavenge ephemerons with surviving keys, and only if none are found, fire ephemerons with unreferenced keys, and scavenge them. Read the class comment for a more in-depth description of the algorithm."

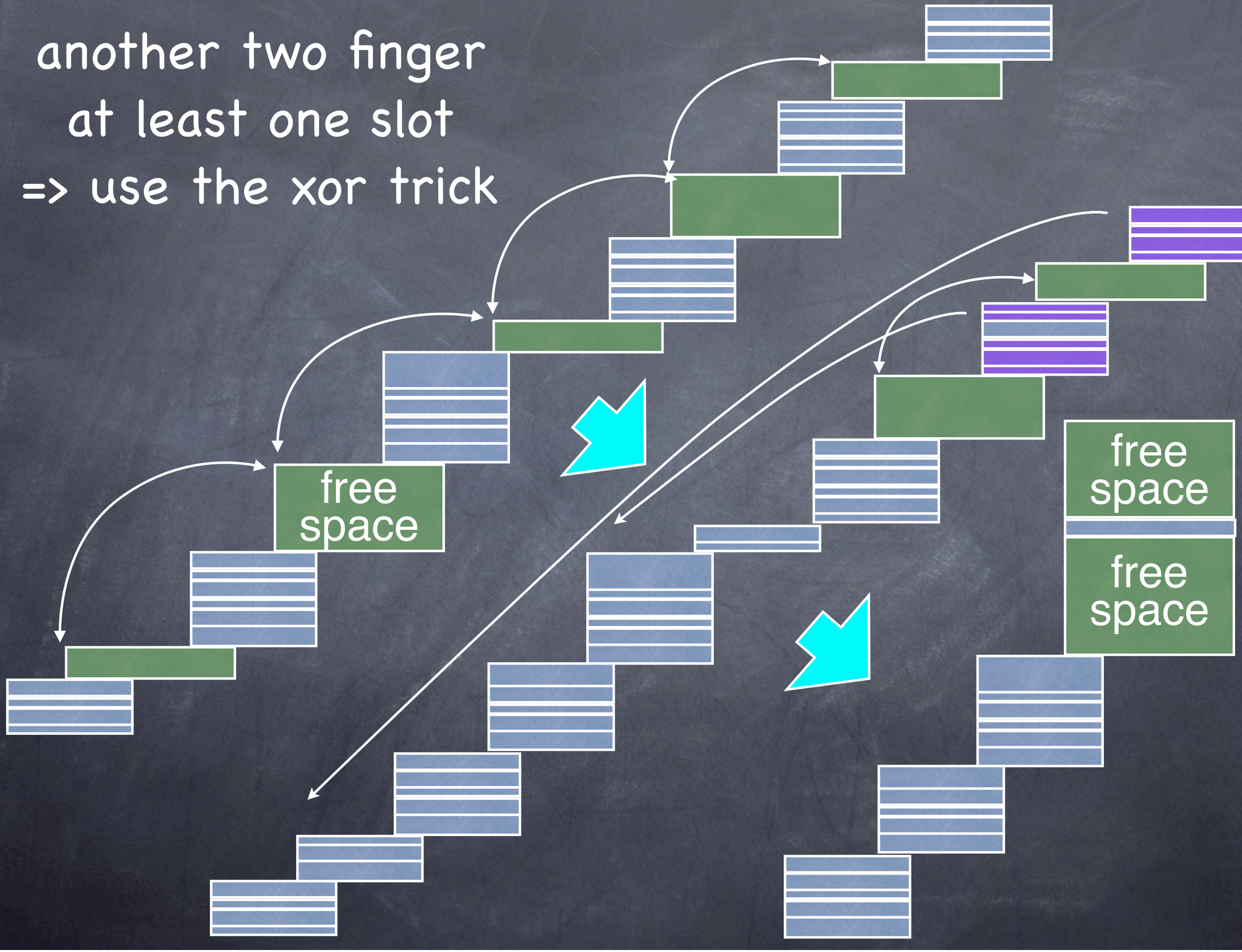
```
| unfiredEphemeronsScavenged |
unfiredEphemeronsScavenged := self scavengeUnfiredEphemeronsInRememberedSet.
self scavengeUnfiredEphemeronsOnEphemeronList ifTrue:
    [unfiredEphemeronsScavenged := true].
unfiredEphemeronsScavenged ifFalse:
    [self fireEphemeronsInRememberedSet.
     self fireEphemeronsOnEphemeronList]
```

object size/heap walk

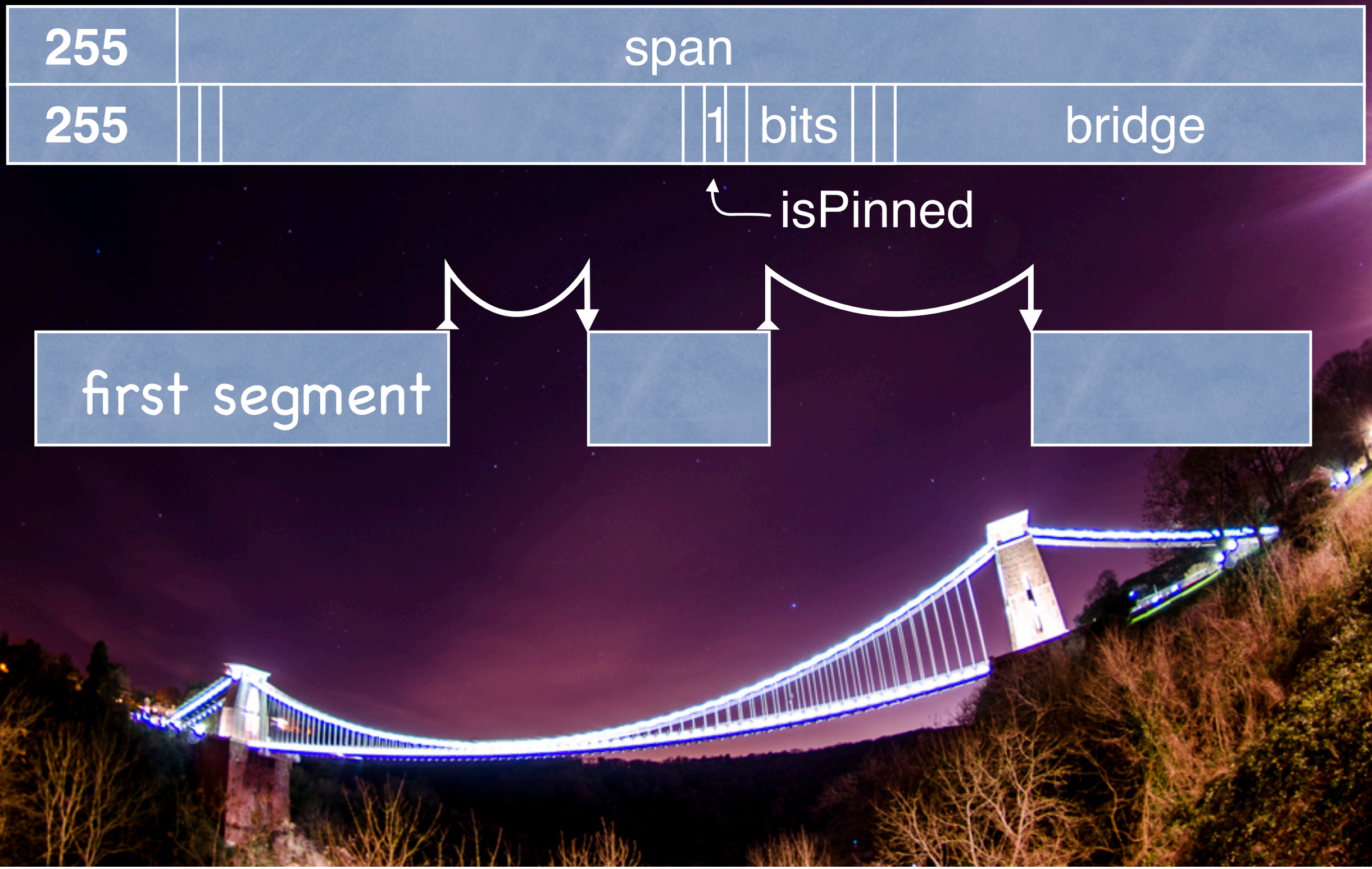



pig compaction
NO THROUGH ROAD
HICKSON RD
if you have a hammer...

another two finger
at least one slot
=> use the xor trick



pins, segments and bridges



achieving inner peace

- A garbage collector is a destructive graph rewriter
- when it goes wrong...

kill more lemmings

@heleneplv

THIS PAGE IS NO LONGER OF THIS WORLD.
STAY ON THIS LAST RESULT IN THE SACRIFICE OF 404 LEMMINGS.
UNLESS YOU DECIDE TO SAVE THEM ALL!
HOVER OVER THEM TO BRING A PARACHUTE
123/404

status

- performance
- functionality
- availability

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64-bits

(new-old)/old

-35% = 1/(1-0.35)
= 1/0.65 = 1.54x

-40% = 1/0.6 = 1.6̇

-50% = 2x