Fearless Concurrency in Python

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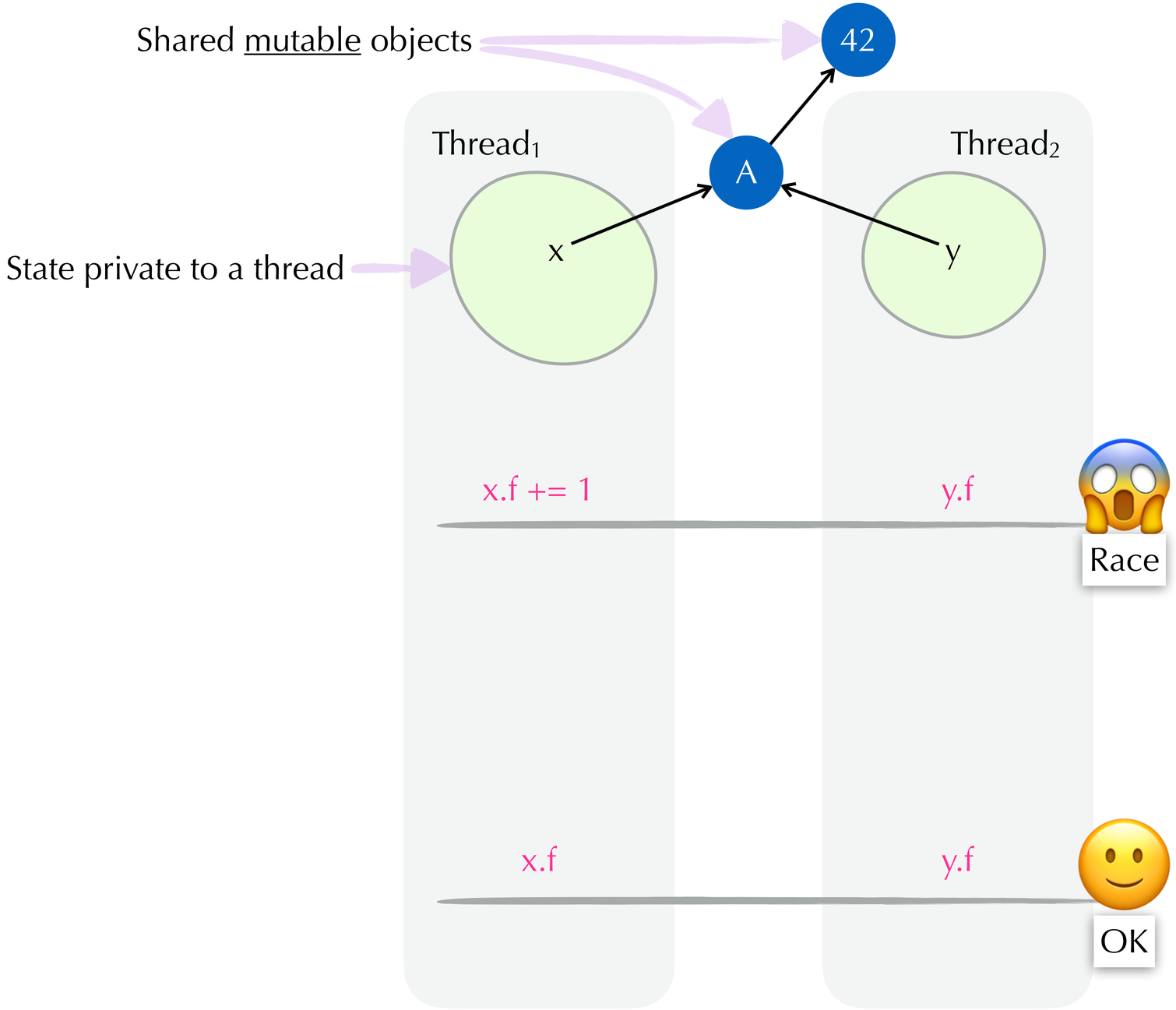
This is the future for free-threaded Python programmers

Data races — ″heisenbugs″



Off to the data races

- The meaning of x.f += 1 depends on whether or not the **object** x **points to** is shared between threads

  There is **no easy way** to tell if x **points to** a shared object

  No easy way to ask on Stack Overflow / ChatGPT

- Data race bugs are heisenbugs

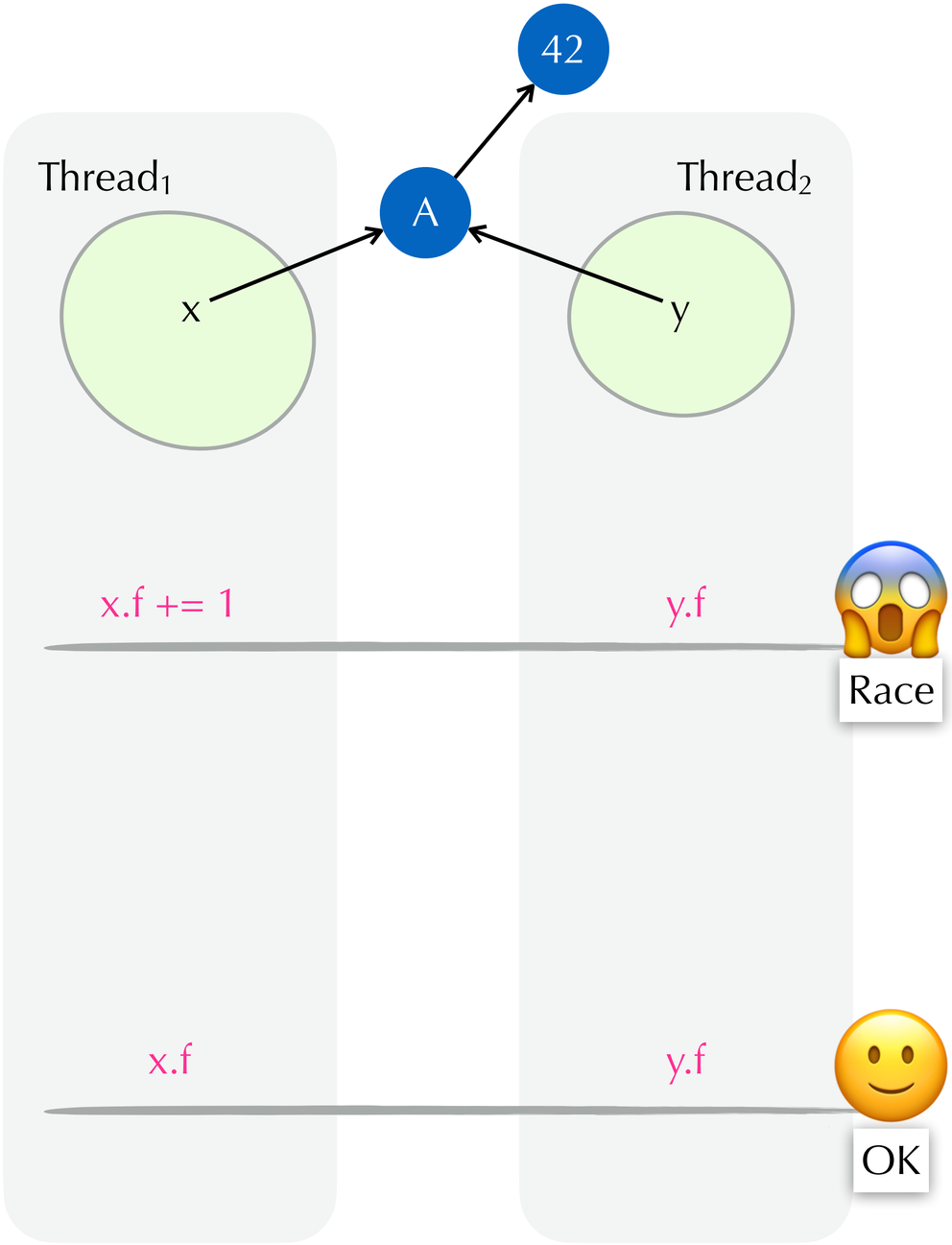
  Often silent wrong results — not a crash

  Hard to reproduce, debug, and fix

- Tools can help — if you realise you need them

  e.g. TSAN — but not familiar to Python programmers

- Costly for the runtime to protect itself against bad code



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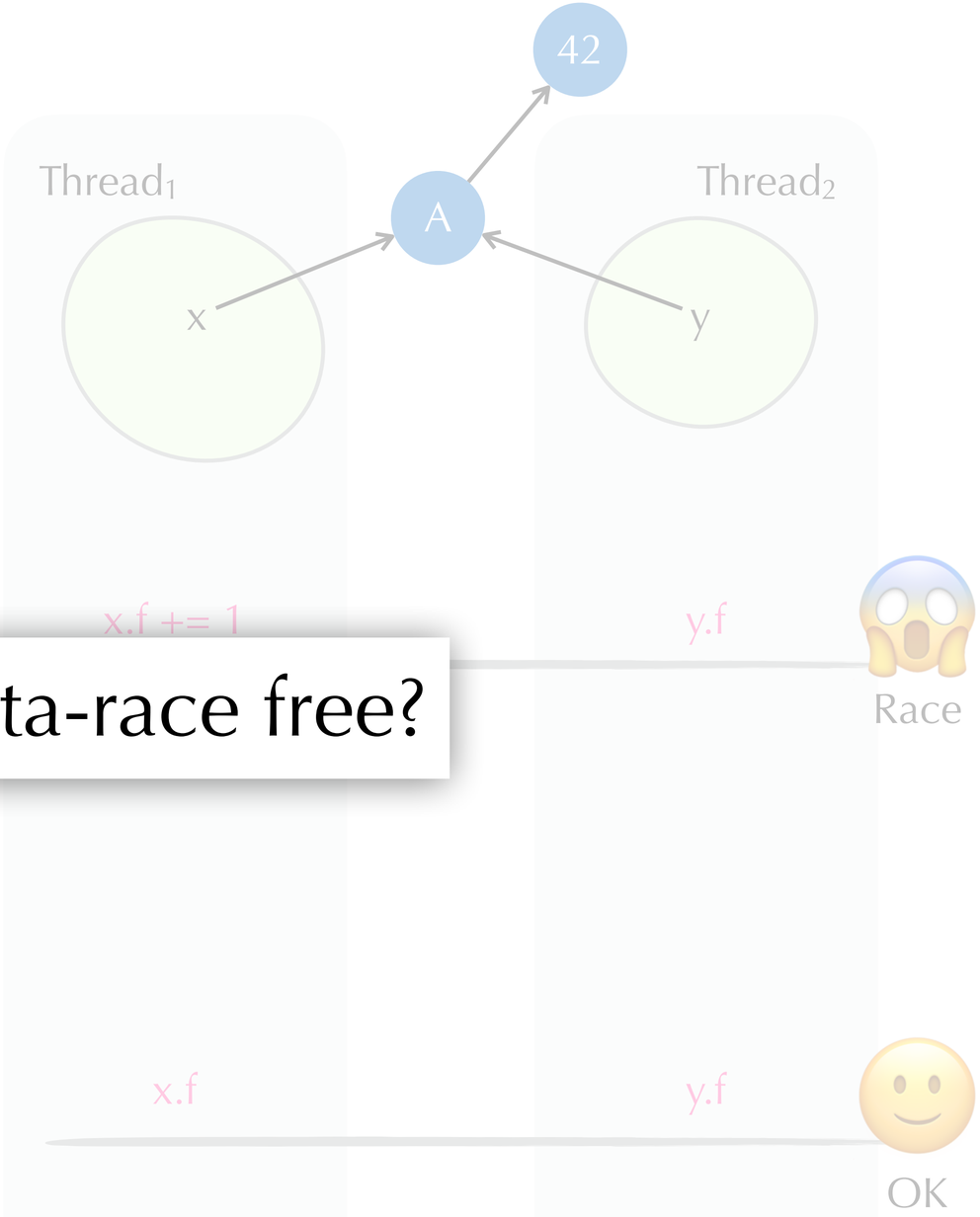
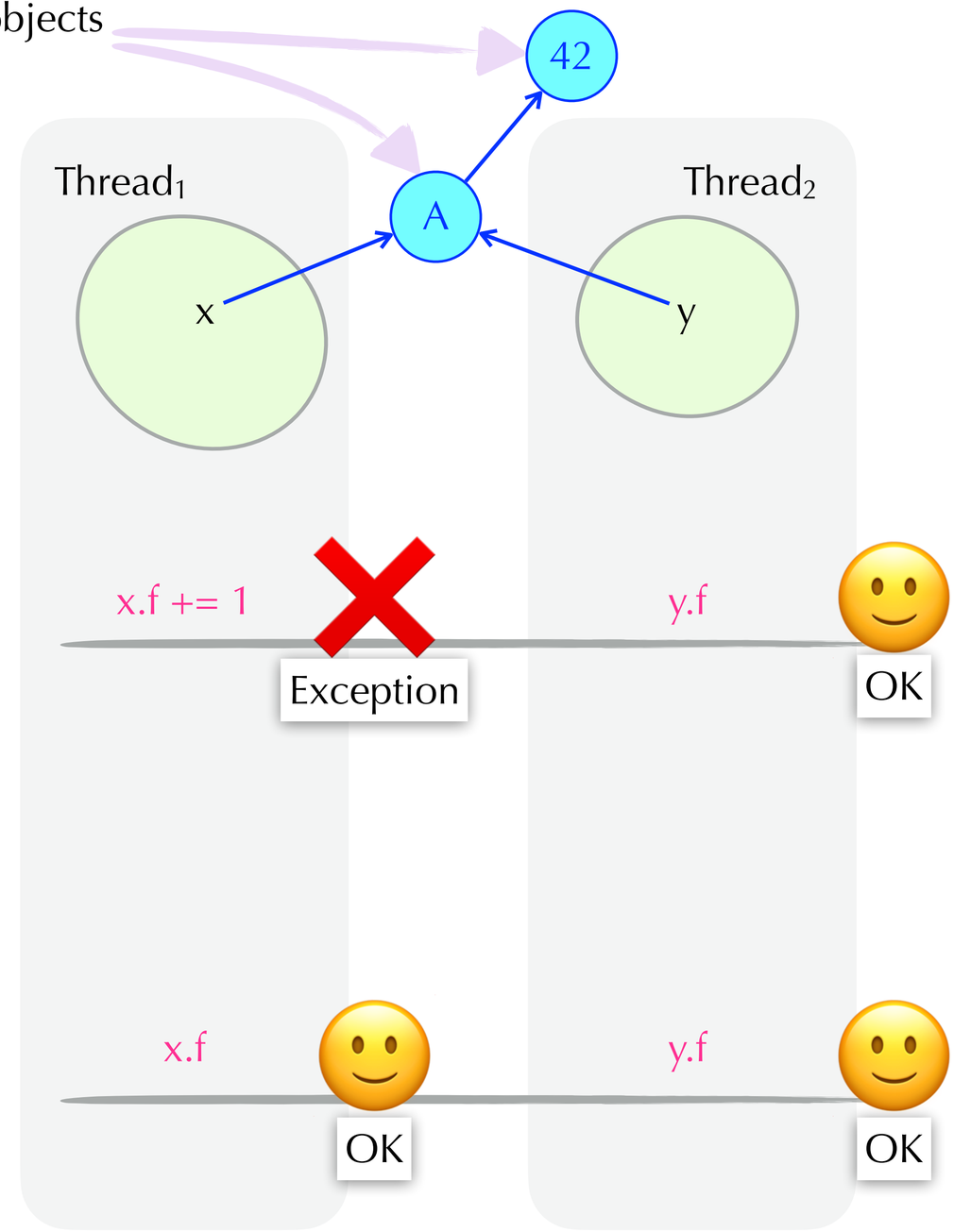


Can we make Python data-race free?

Shared immutable objects

What about deeply immutable state?

- **Model**
  - All shared memory is immutable — so there can be no data races
  - Can be checked efficiently at run-time
- **Advantages**
  - Mutating shared memory becomes an error — not a data race
  - Explainability goes up
  - Enables optimisations for the runtime
- **However**
  - Rules out mutation (which is common in Python)
  - Cannot transfer data without making it immutable



What about ownership á la Rust?

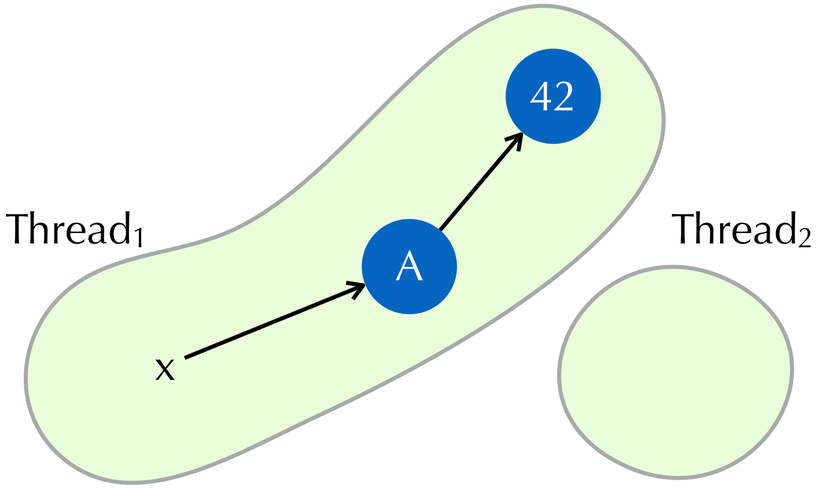
- **Model**

  Object with RC > 1 cannot be mutated

- **Advantages**

  Safe transfer of mutable objects (if RC = 1)

  Can construct safe locking protocols



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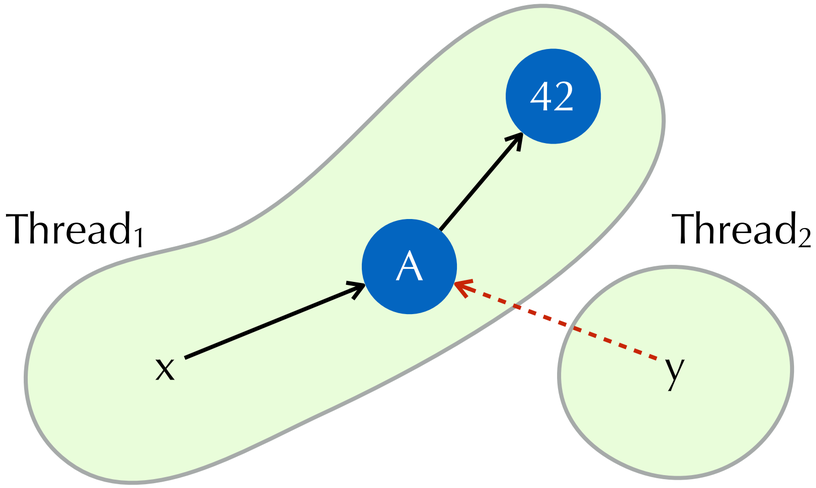

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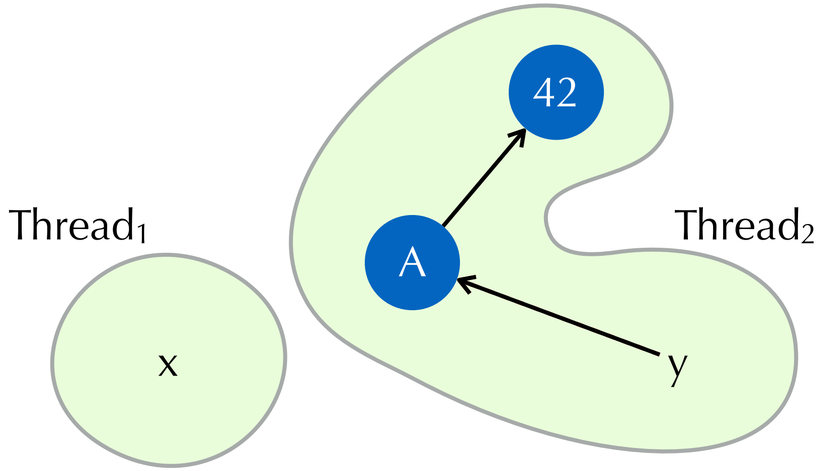

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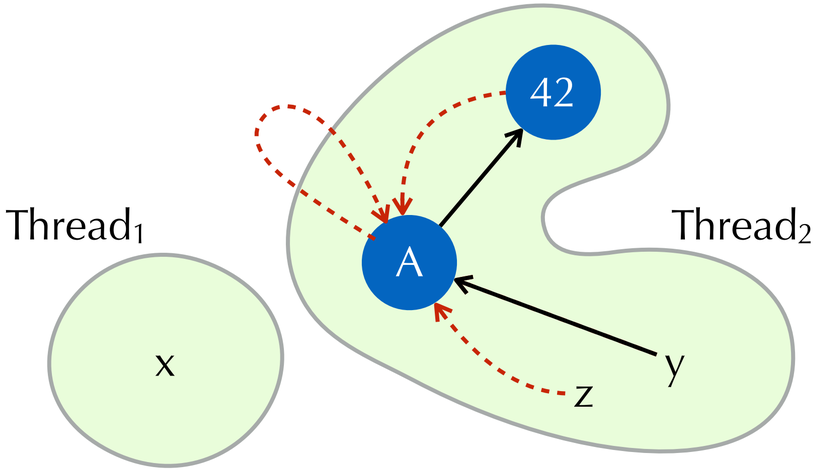

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  Built on static types + static analysis (borrow checker)

  Massively restricts shape of object graphs

Would force rewriting most existing Python programs!

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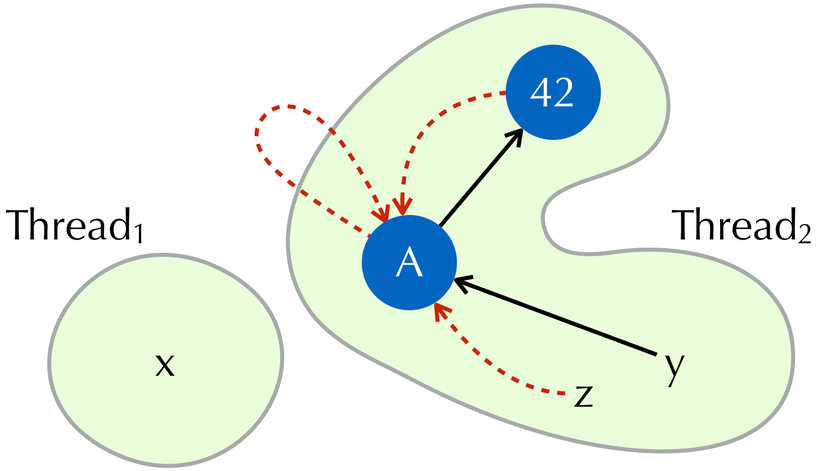

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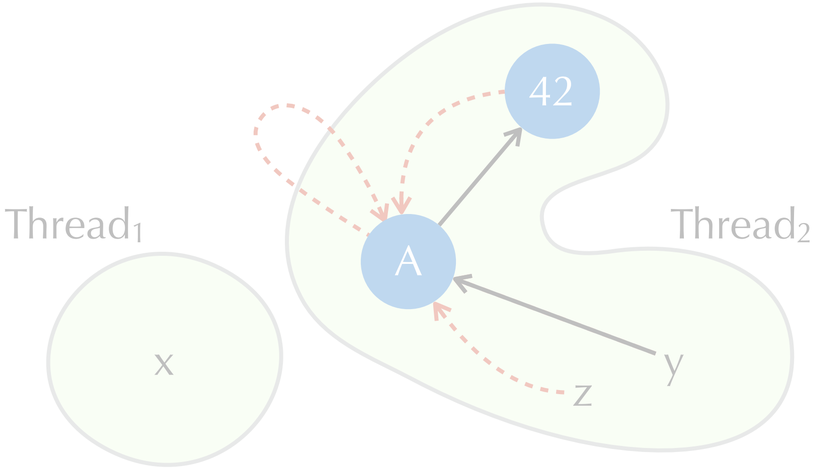

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Does a more Pythonic solution exist?

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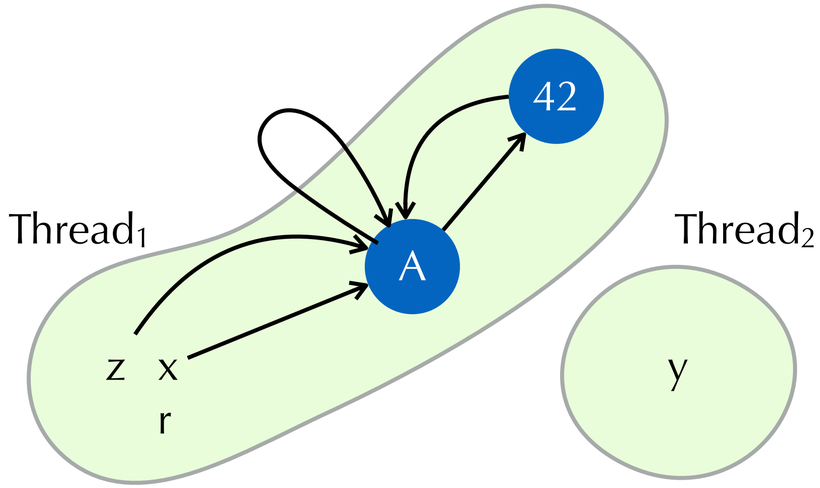
Lungfish — Pythonic ownership!



- **Region-based ownership**
  - More permissive than Rust — yet data-race free
  - Can be checked efficiently at run-time
  - Sensible error messages
- Region = group of mutable objects
  - Isolated
  - Share, transfer, make immutable — together
  - Can be nested
- References into region tracked dynamically using a ”Borrow Count”

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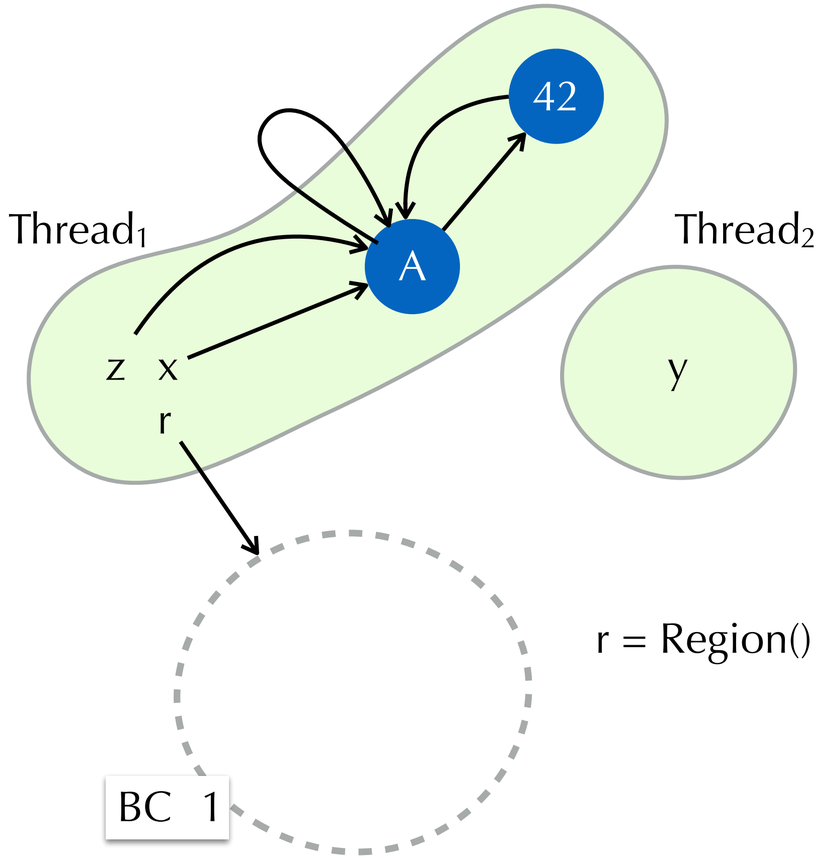

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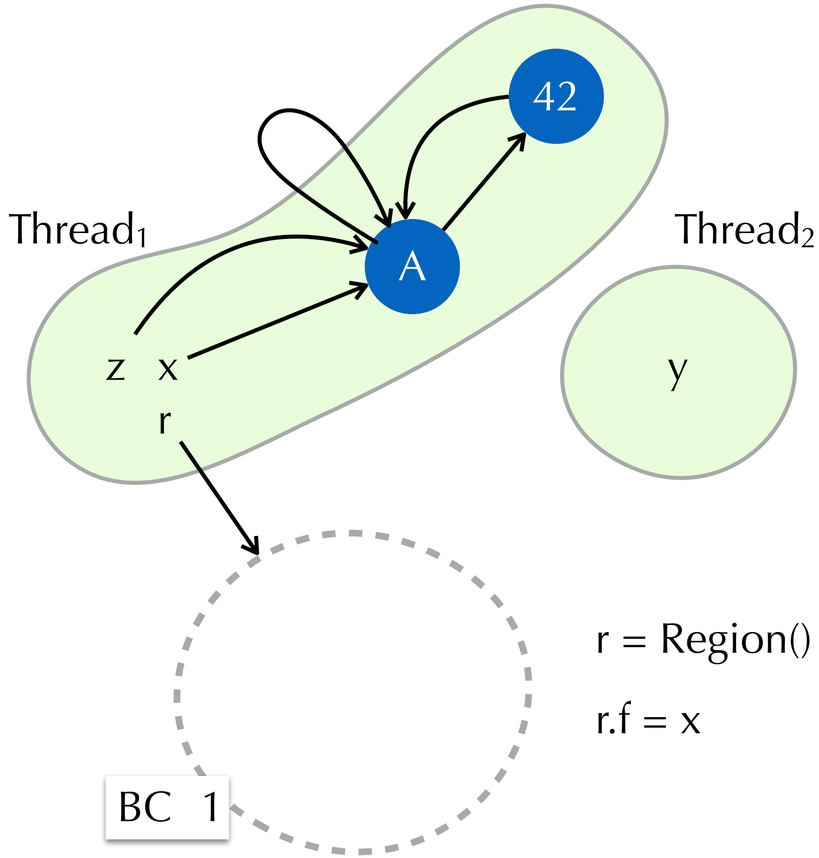

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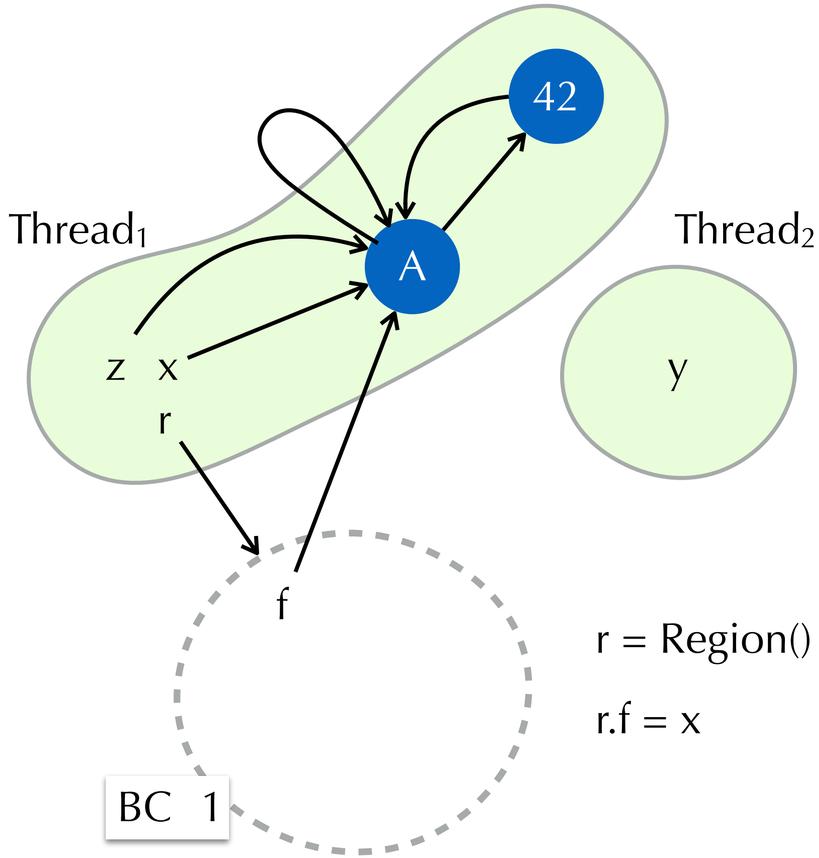

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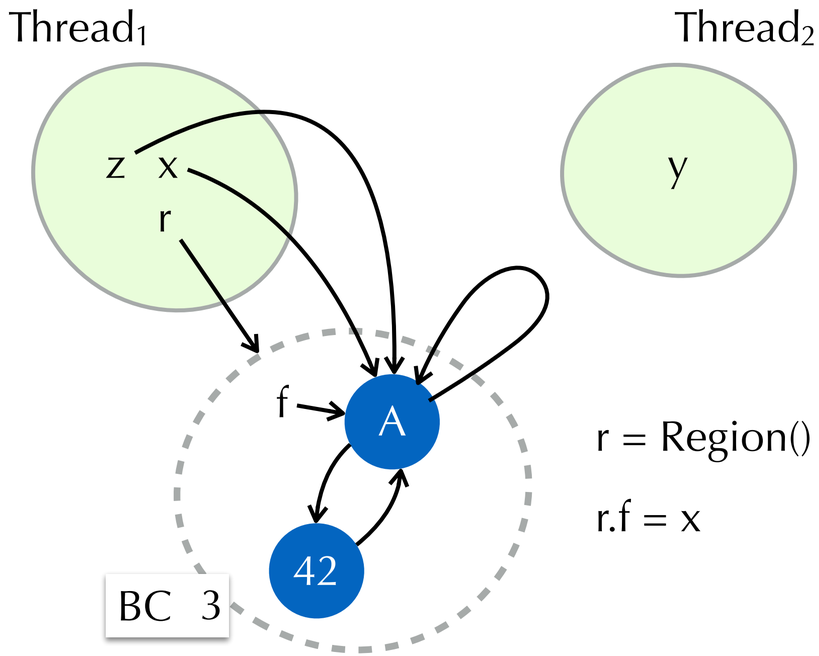

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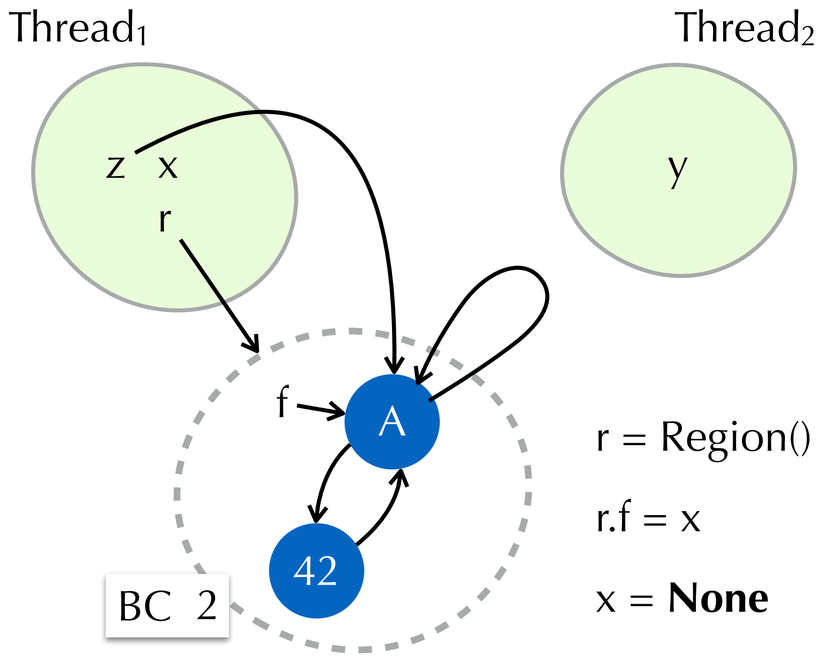

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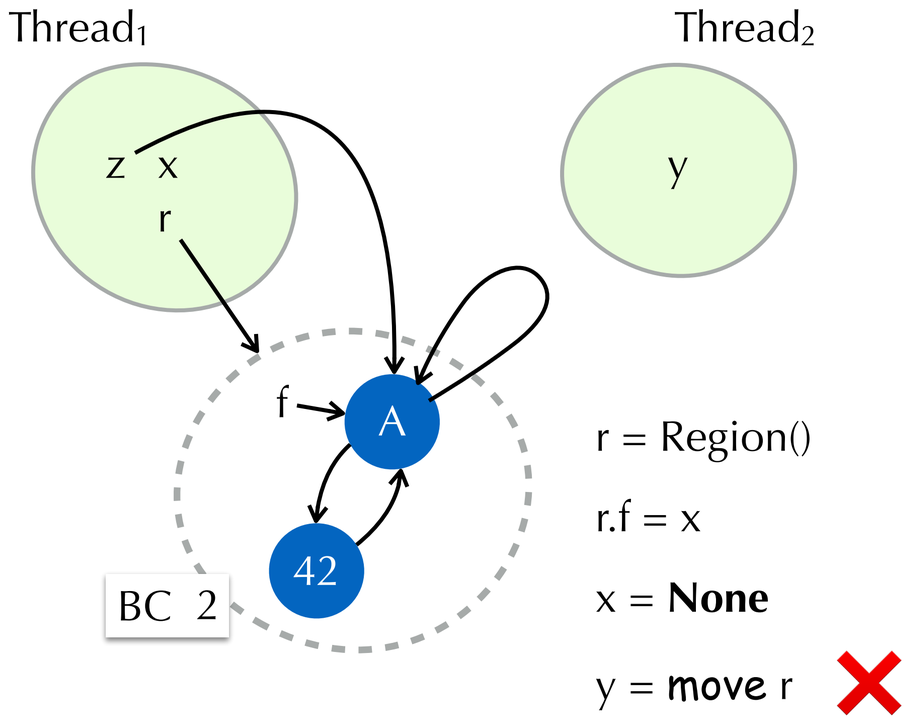

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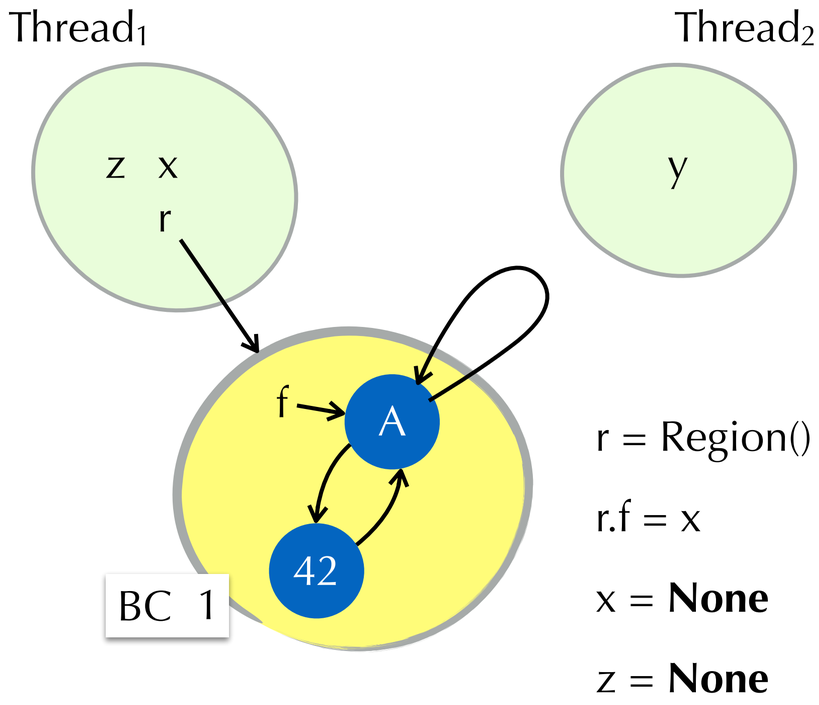

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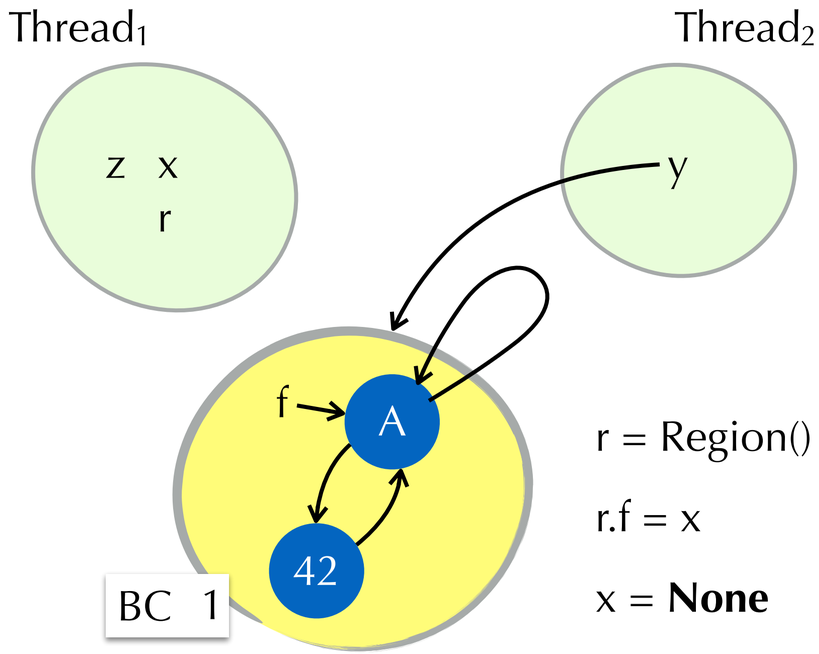

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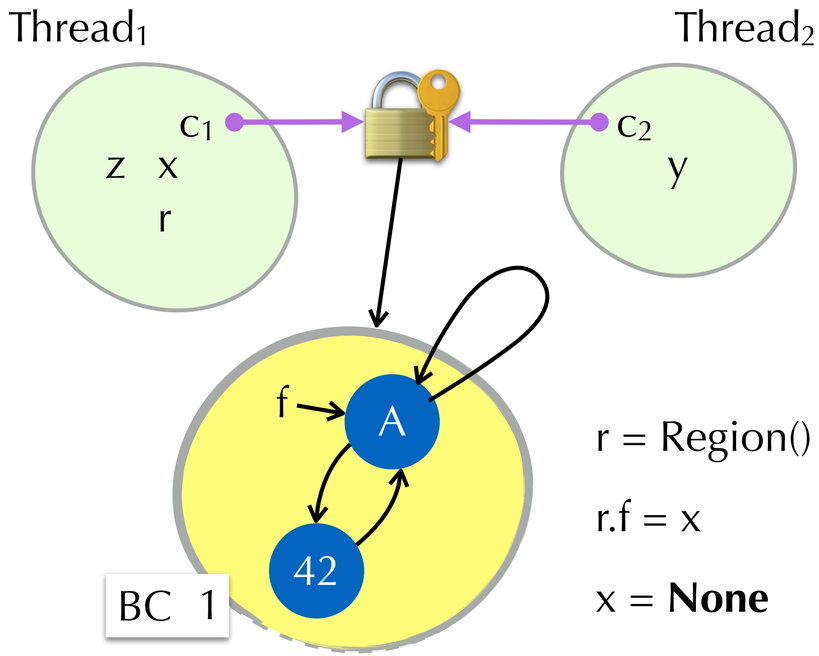

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r.f = x

x = **None**

z = **None**

y = **move** r

c1, c2 = **share** y

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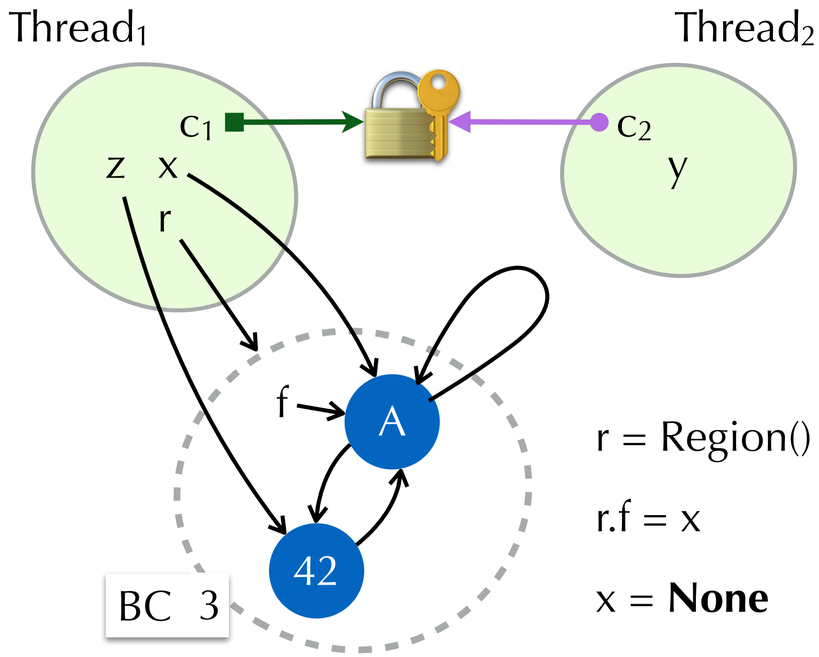

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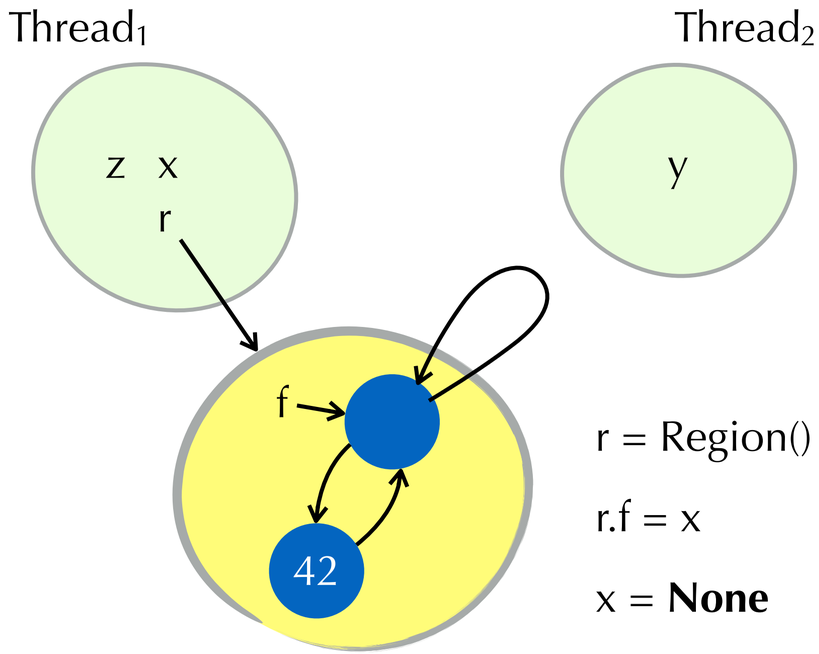


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r = Region()
r.f = x
x = None
z = None
freeze(r)
# x,  y = …
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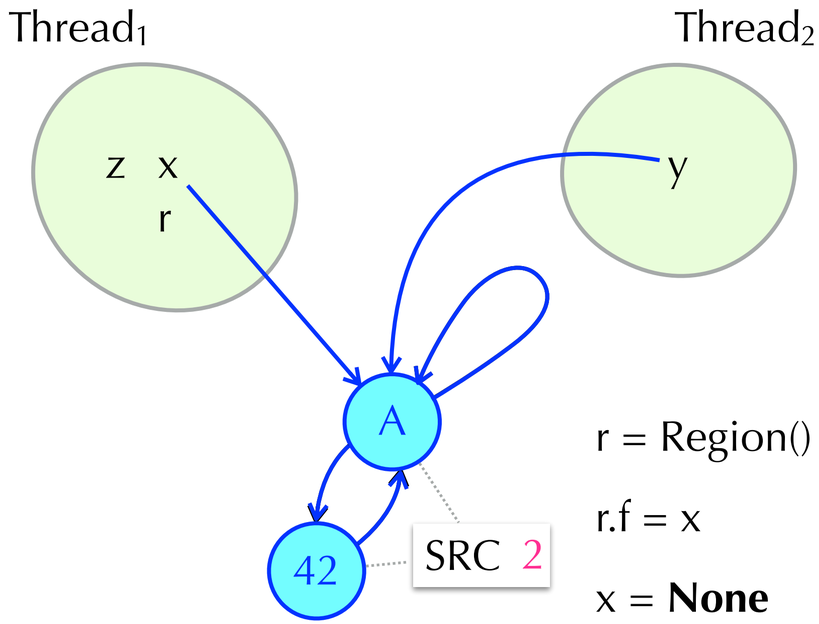


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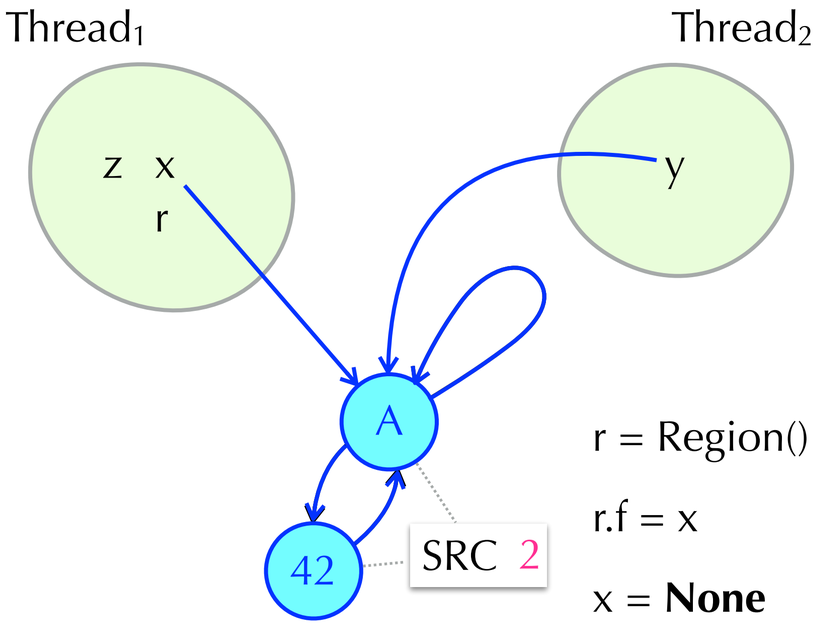


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✅ Transfer

✅ Mutable sharing

✅ Immutable sharing

✅ Enables optimisations

– Efficient GC

– Immutable obj. rep.

A Plan for "Fearless Python"

- We propose to make Python data-race free through a series of Python Enhancement Proposals:

  PEP A: Deep Immutability

  Implementation status (**note:** on-top of 3.12): 99% ✅

  PEP B: Manage cyclic immutable garbage with reference counting + atomic reference counting of immutable objects

  Implementation status: 80% 🚧

  PEP C: Share **immutable** data between threads and subinterpreters (PEP734)

  Implementation status: ≈50% 🚧

  PEP D: Share **mutable data** between threads and subinterpreters using regions

  Implementation status: 🤷 🚧

- Lungfish offers fearless concurrency both with and without GIL(s) — free-threaded or with subinterpreters

We thank the **Faster CPython team** for helping us refine these ideas for ~2 years

Now we are looking forward to **working with all of you** to explore the possibility of "Fearless Python"!


Matt J


Sylvan


Matt P

Go here for more info and a copy of this presentation:

https://microsoft.github.io/verona/pyrona.html


Fridtjof


Lungfish


Tobias