Notification Proxies: update TC39 May 2013

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with help from Mark S. Miller, based on idea by E. Dean Tribble

Why Notification Proxies?

- A simpler alternative to direct proxies

- Direct Proxies: require **runtime assertions** on trap return values to check non-configurable/non-extensible invariants

- Adds **runtime overhead**, even when proxy handlers “behave”

- Adds **integrity hazard**: if we forget an assertion, invariant can be violated

- Adds **spec complexity**: invariants are different for each operation

  - Especially complex for ops that return collections,
    e.g. `Object.getOwnPropertyNames`

Notification Proxies

- Key idea: traps are just notification callbacks, they don’t get to directly return the *result* of the intercepted operation

- Intercepted ops are always forwarded to the target after invoking the trap
    - No need to manually “forward” the operation

- Trap can optionally return a function to be invoked as a *post-trap*
    - Post-trap can observe the result, but cannot change it

Example

- With direct proxies:

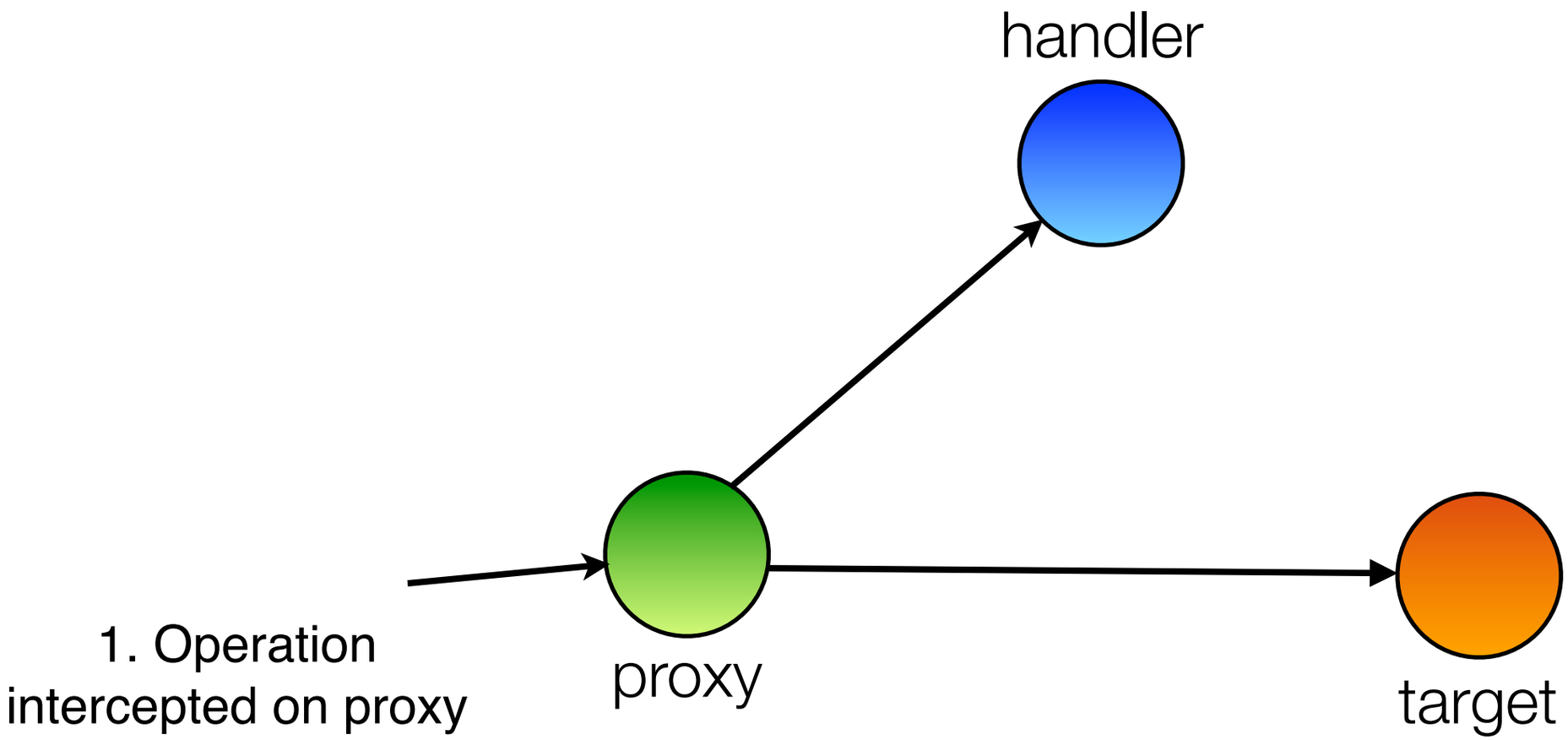
```
var target = {};
var handler = {
  get: function(target, name, receiver) {
    console.log(“getting: ” + name);
    var result = Reflect.get(target, name, receiver);
    console.log(“got: ” + result);
    return result;
  }
};

var proxy = new Proxy(target,handler);
```

Example

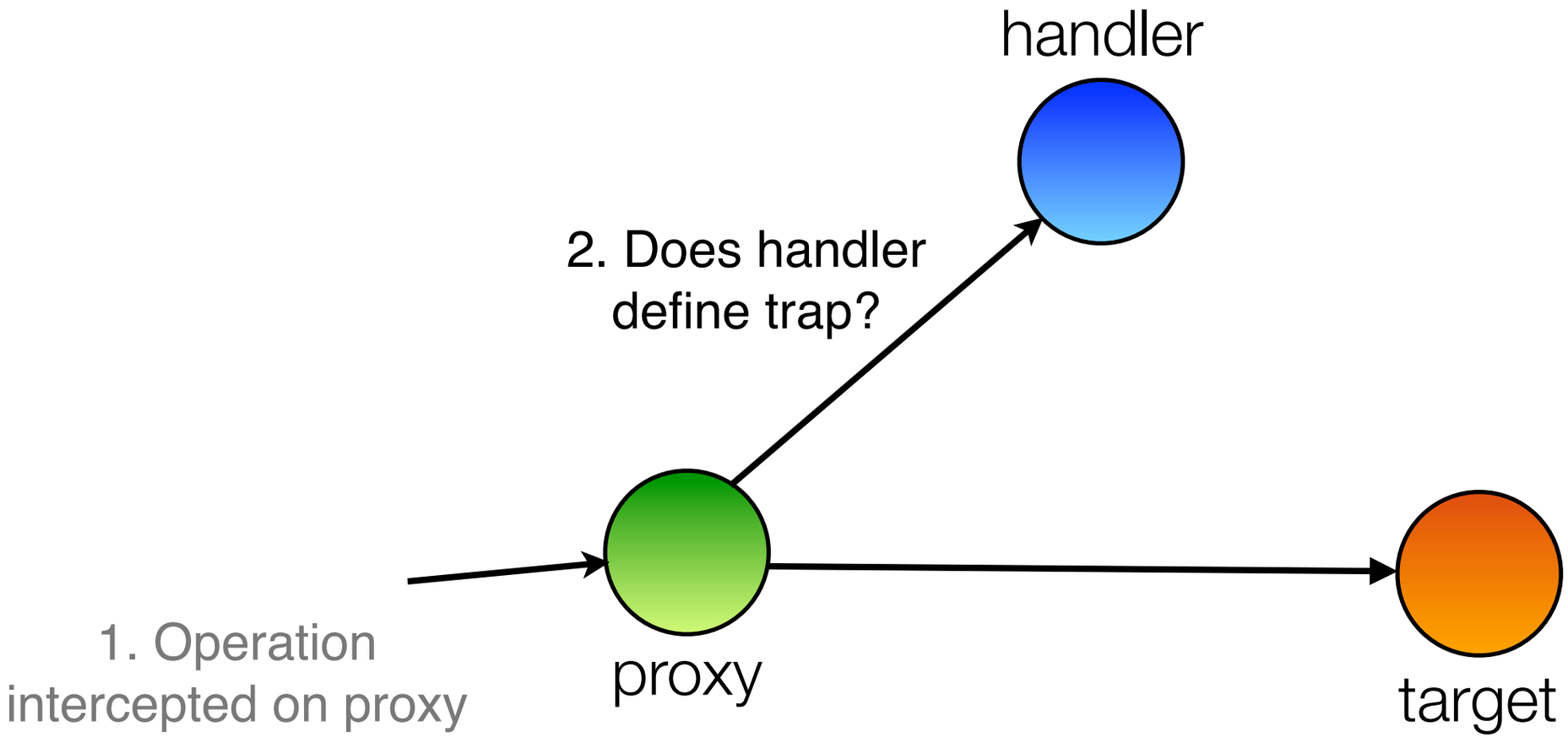
- With notification proxies:

```
var target = {};
var handler = {
  onGet: function(target, name, receiver) {
    console.log(“getting: ” + name);
    return function(target, name, receiver, result) {
      console.log(“got: ” + result);
    }
  }
};

var proxy = new Proxy(target,handler);
```

Direct Proxies

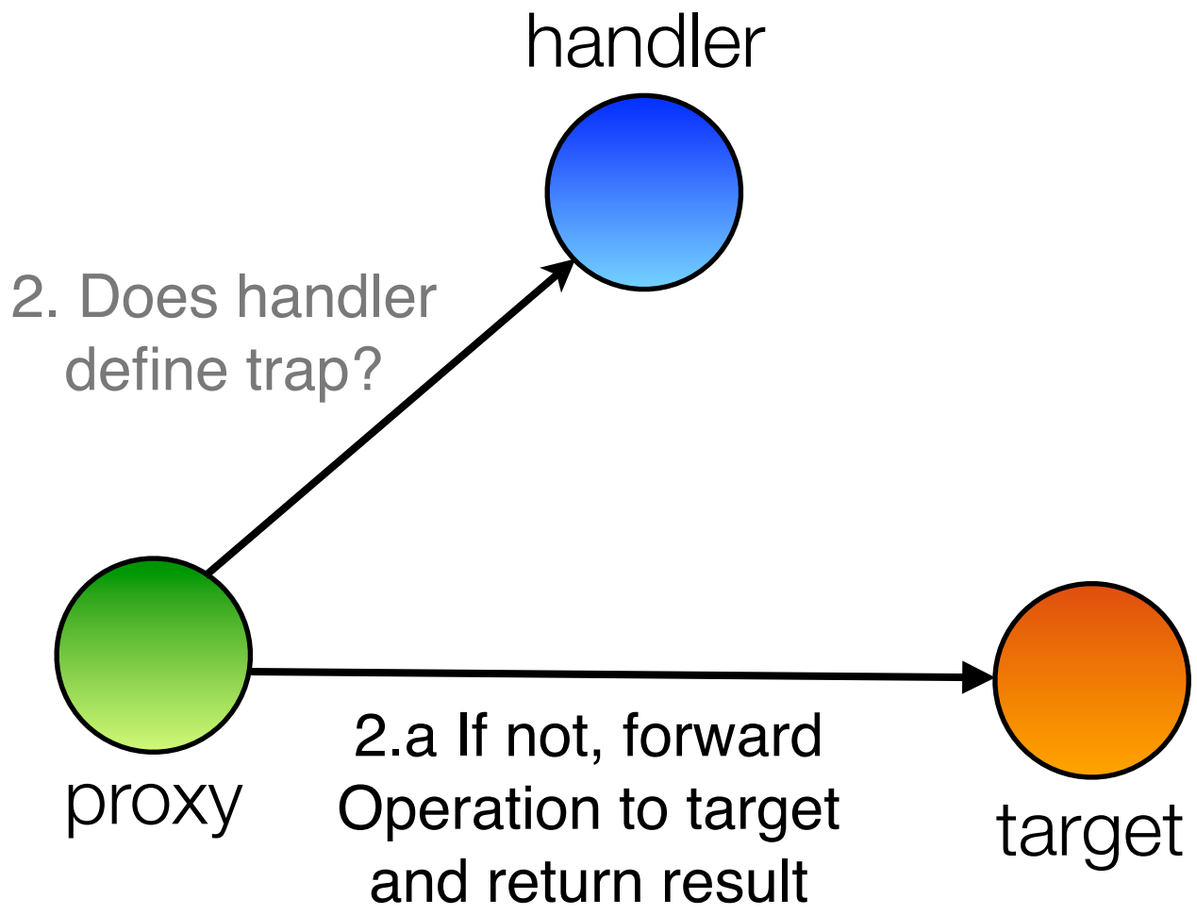


Direct Proxies



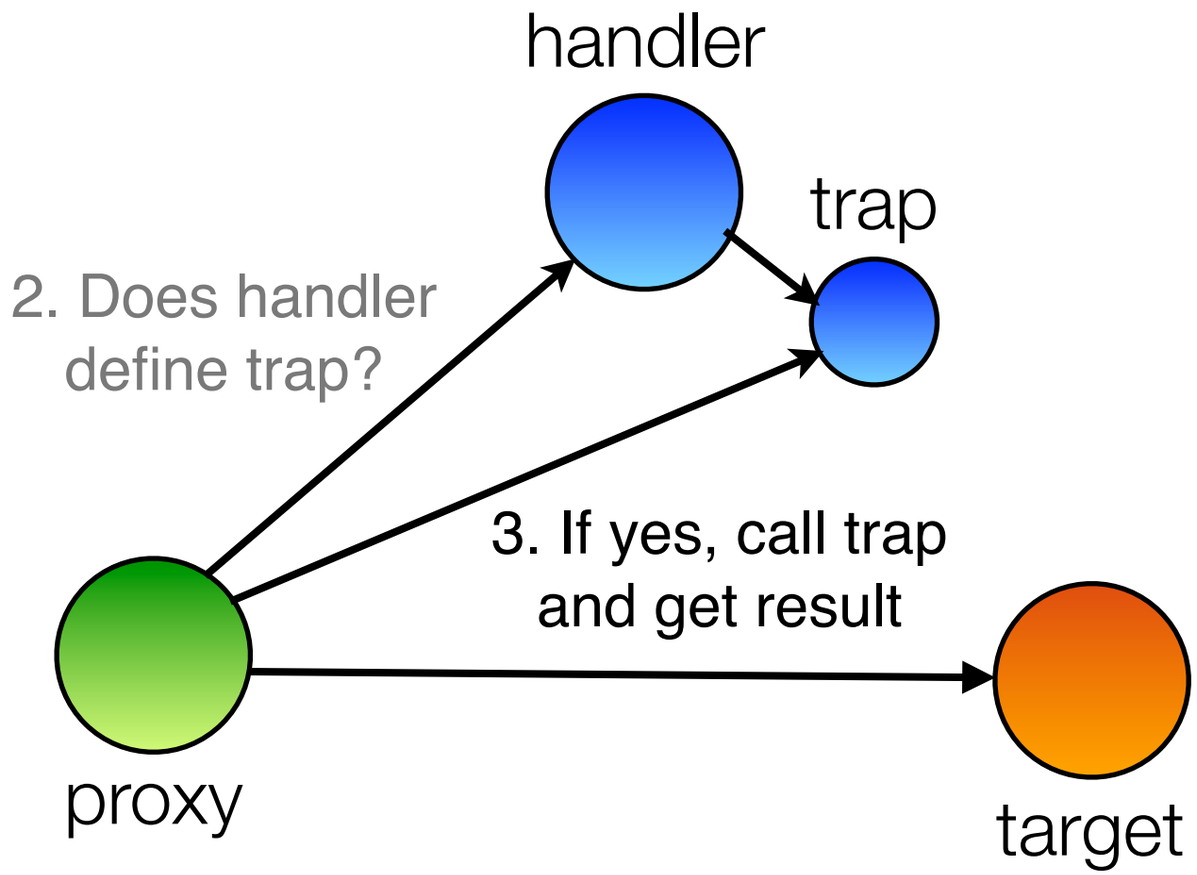

```
trap = handler[“get”]
```

Direct Proxies



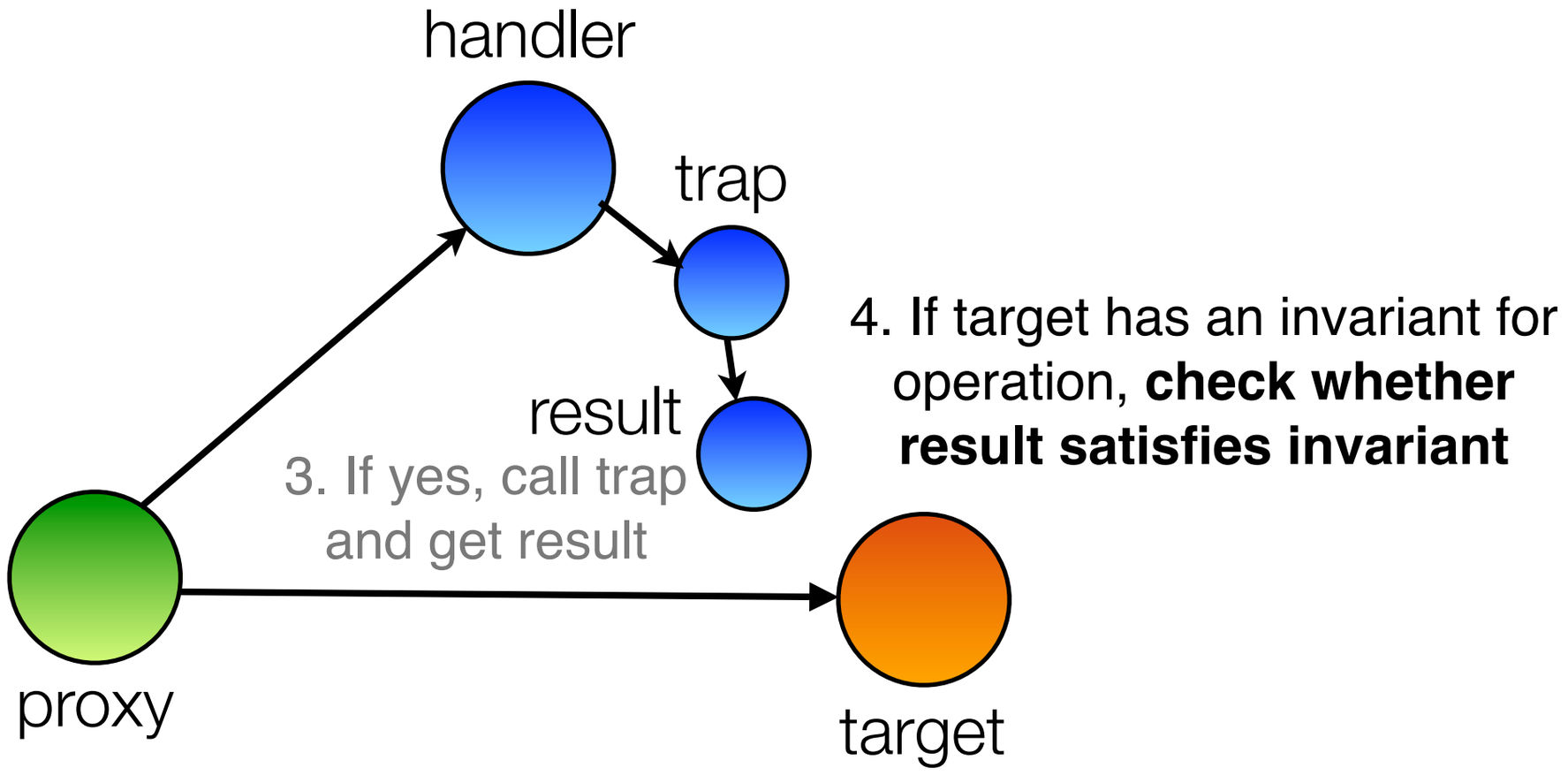

```
return target.x;
```

Direct Proxies



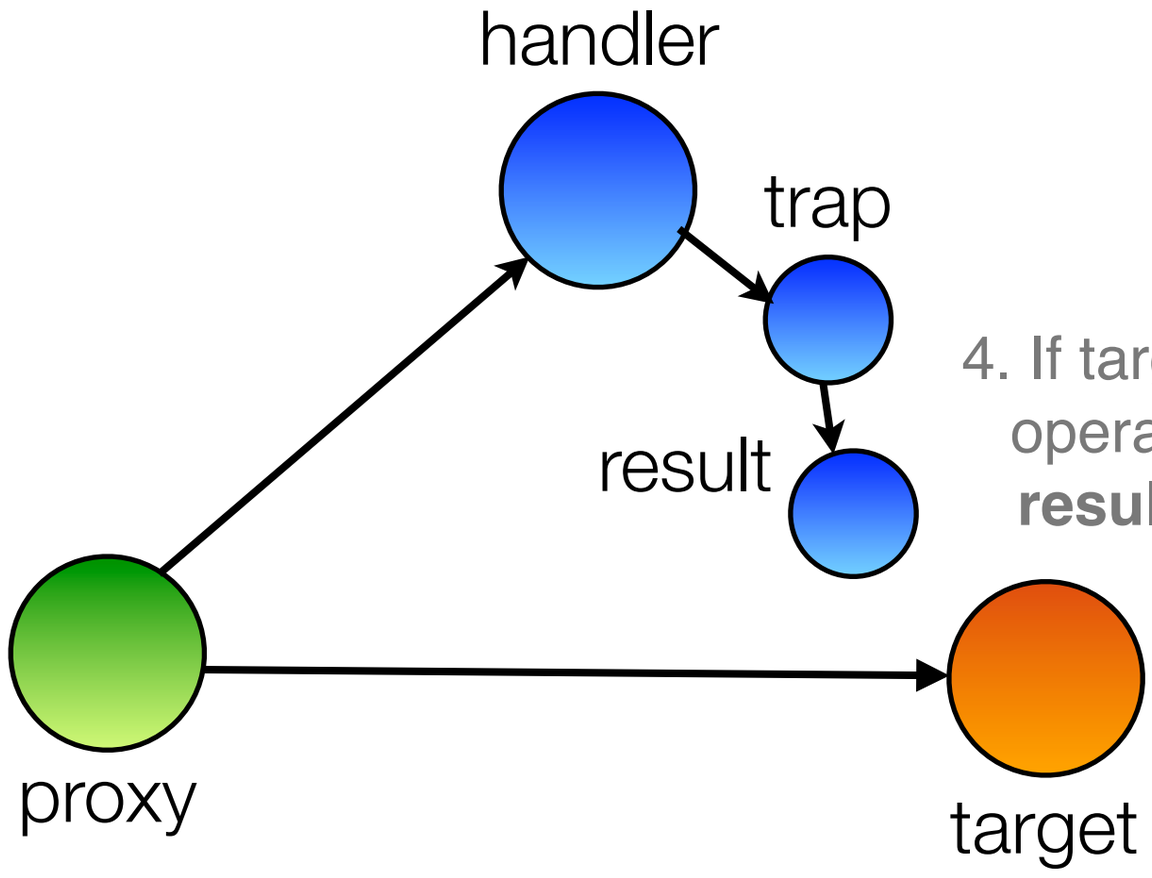

```
result = trap.call(handler, target, “x”, proxy);
```

Direct Proxies




```
var desc = Object.getOwnPropertyDescriptor(target, “x”);
if (desc && !desc.configurable && !desc.writable) {
  assert [[SameValue]](result, desc.value);
}
```

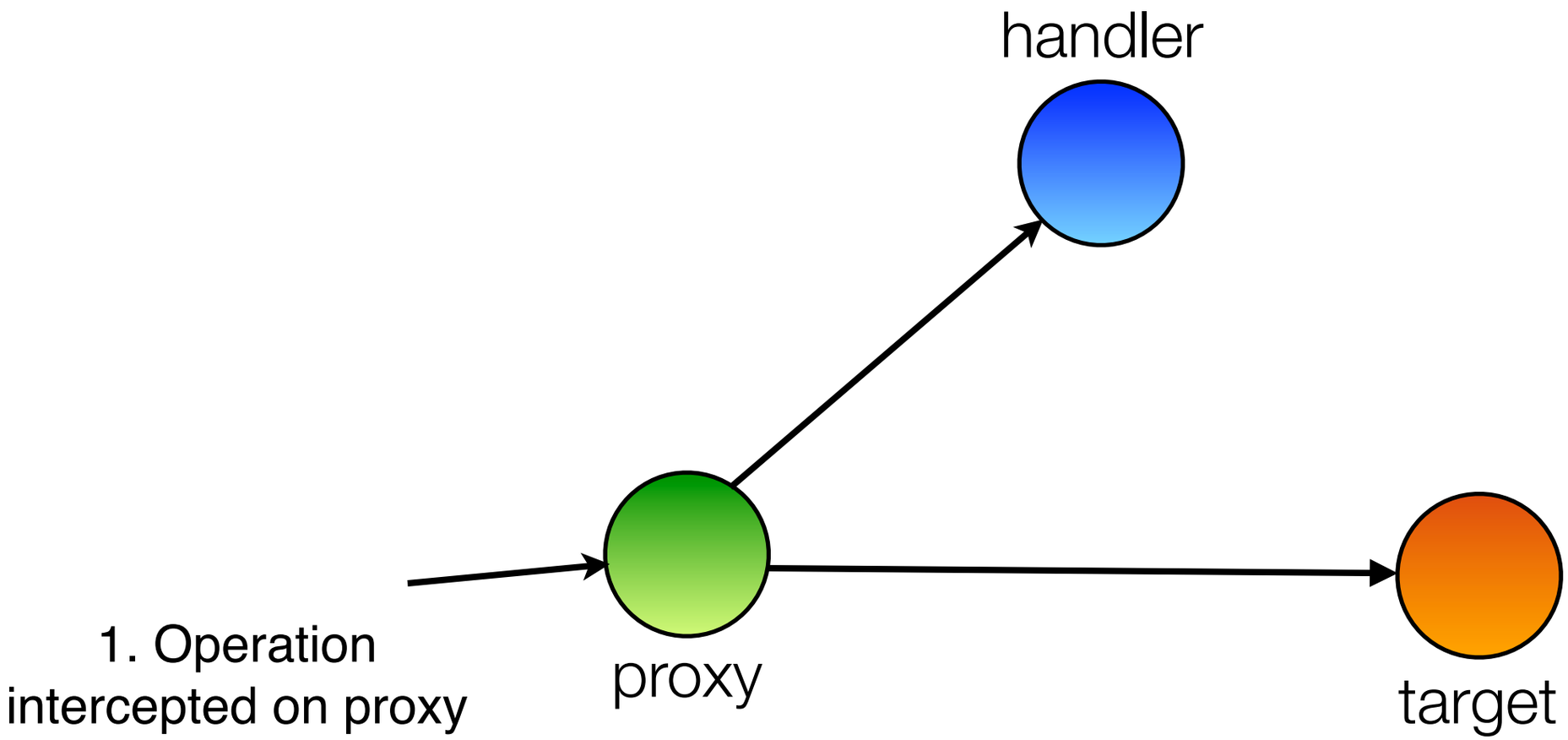
Direct Proxies



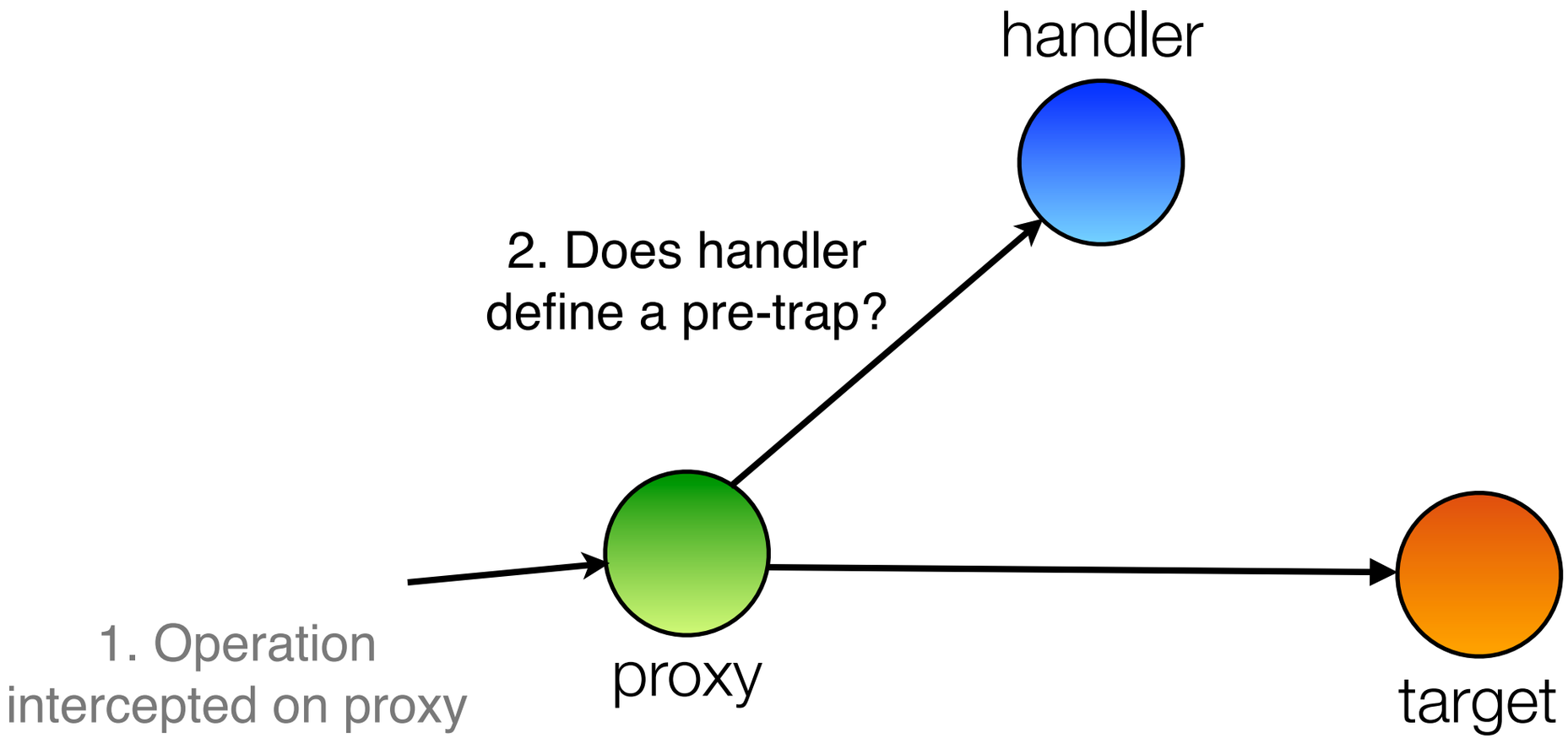
4. If target has an invariant for operation, **check whether result satisfies invariant**

5.a If yes, return result
5. b If not, throw TypeError

Notification Proxies

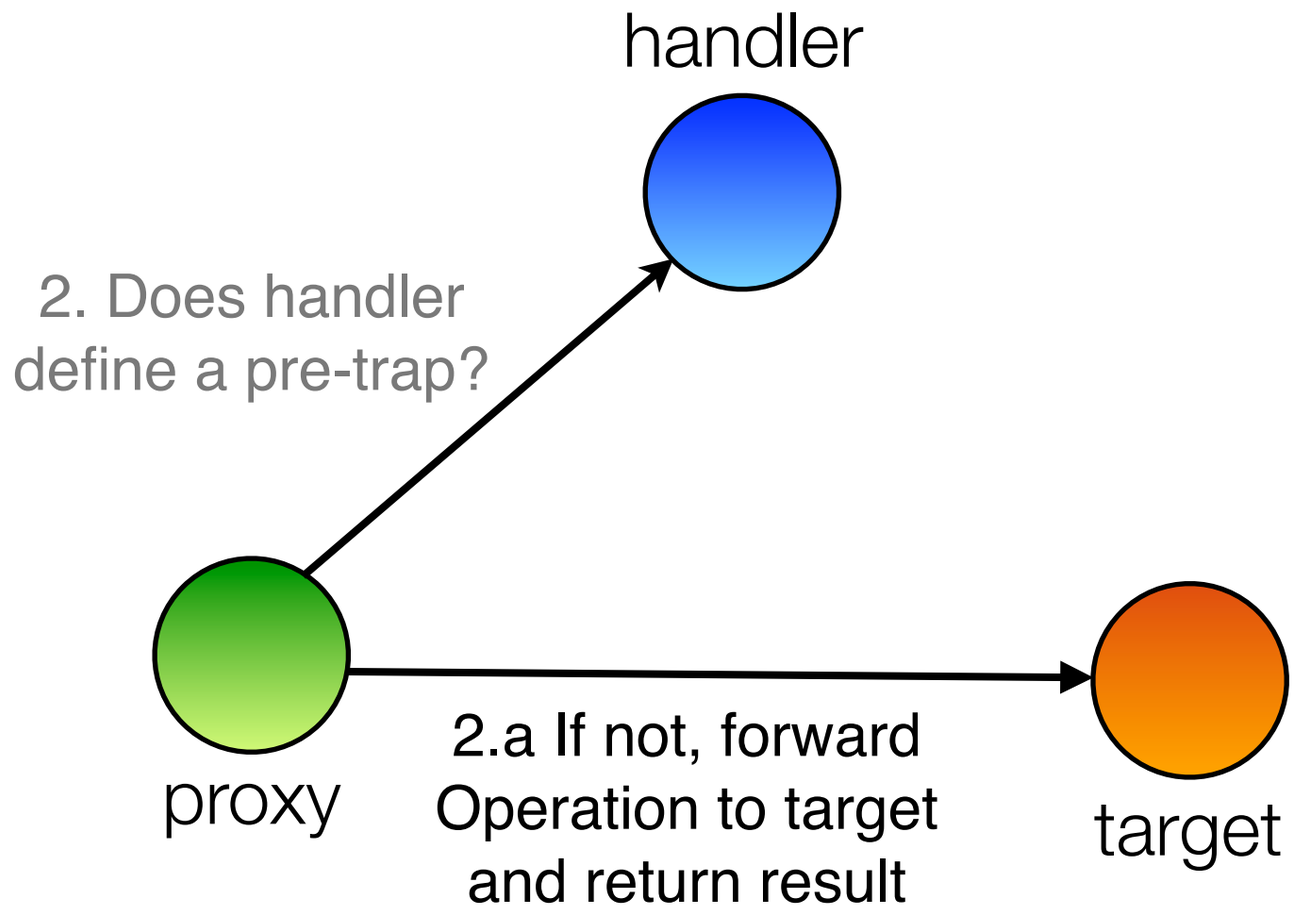


Notification Proxies



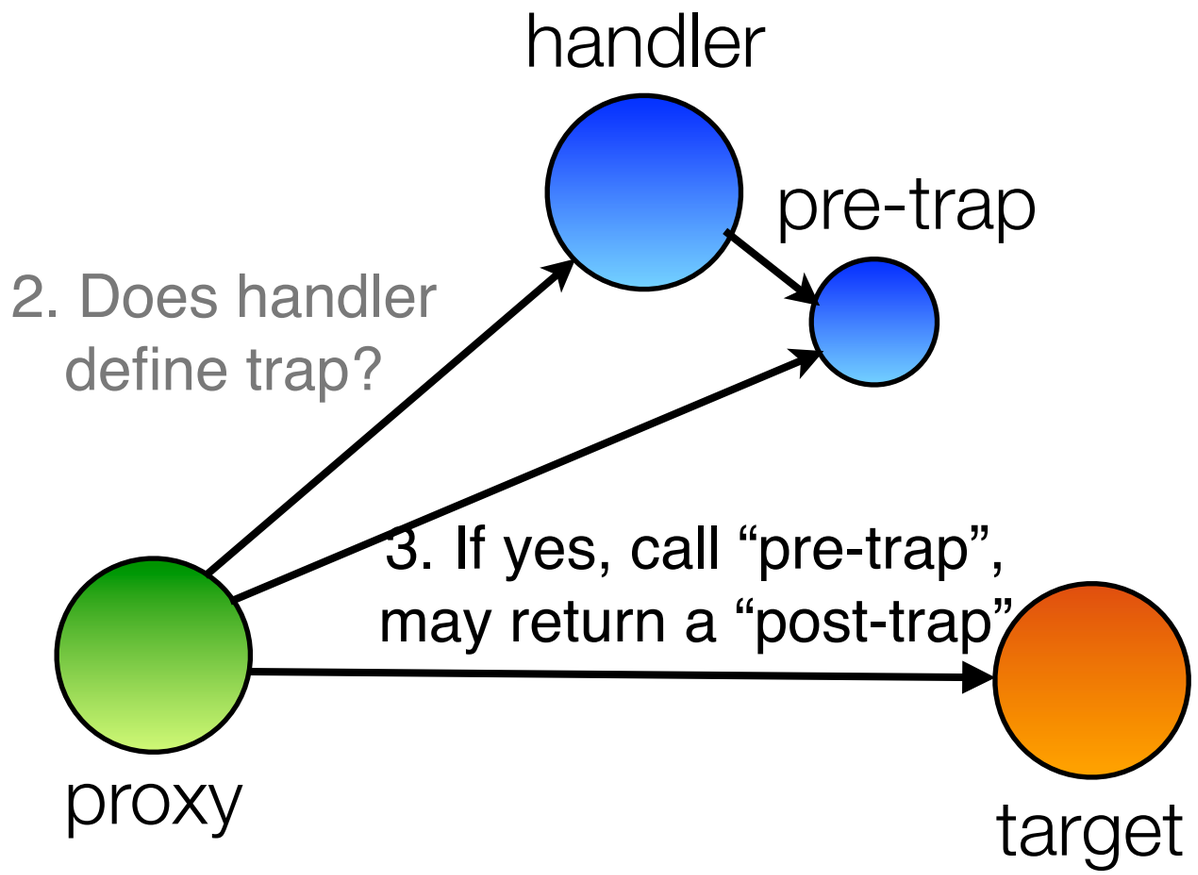

```
trap = handler[“onGet”]
```

Notification Proxies



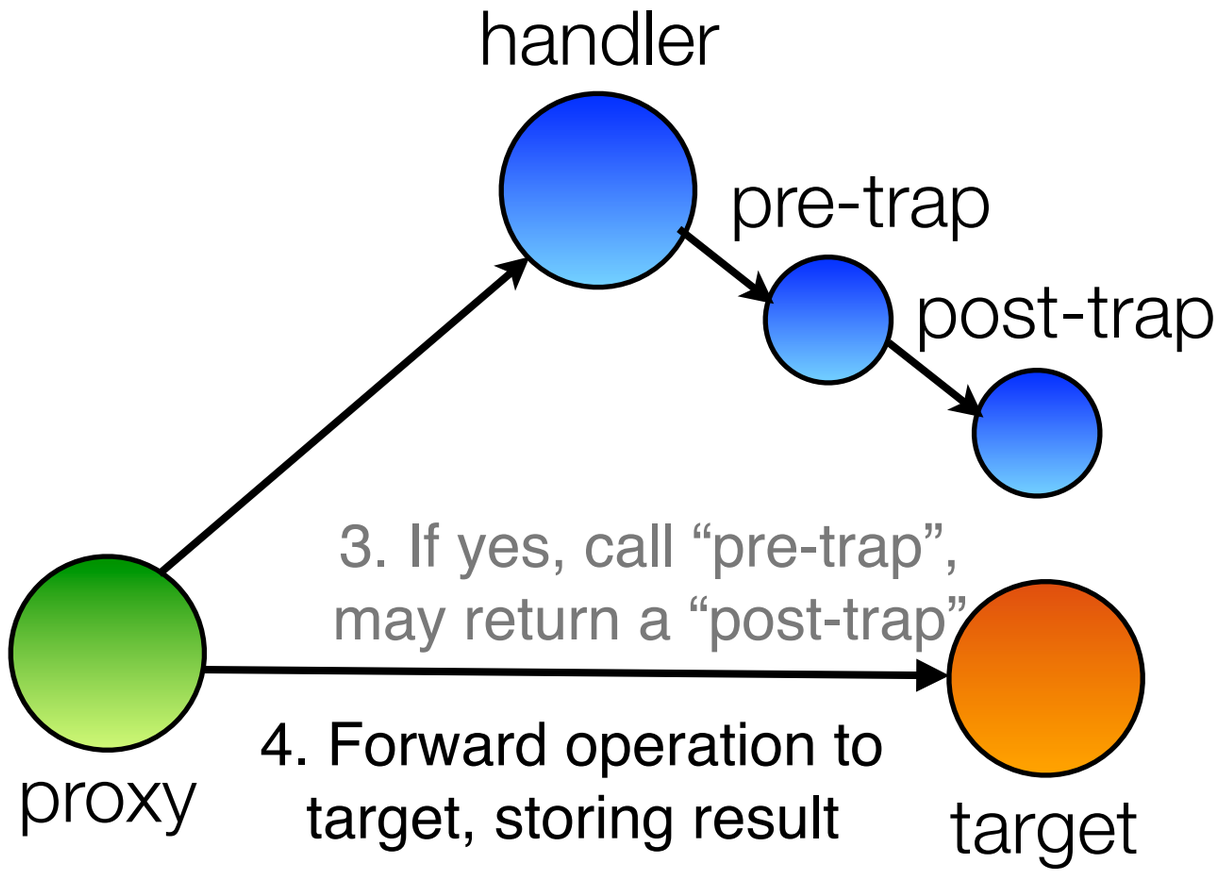

```
return target.x;
```

Notification Proxies



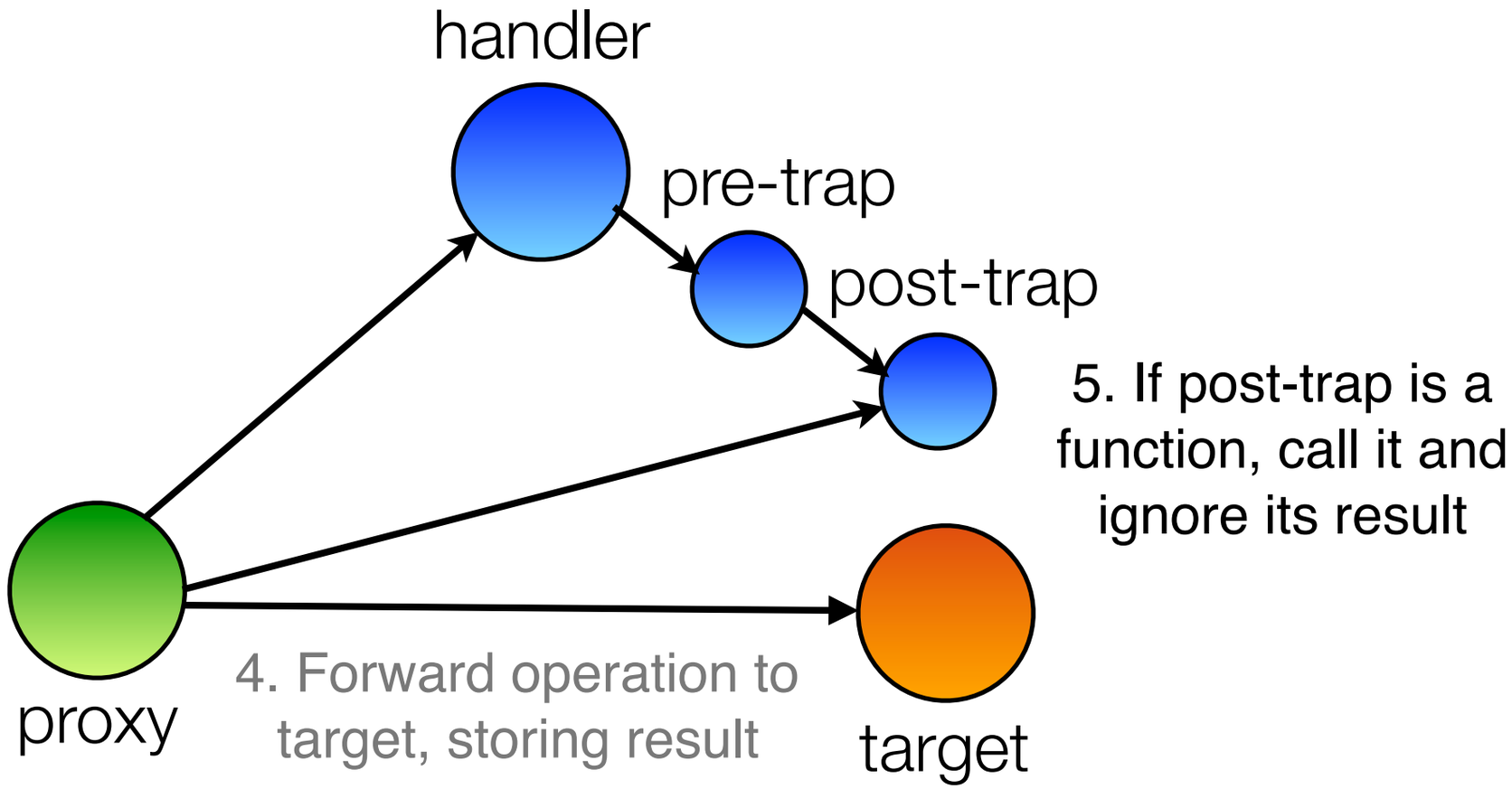

```
postTrap = trap.call(handler, target, “x”, proxy);
```

Notification Proxies



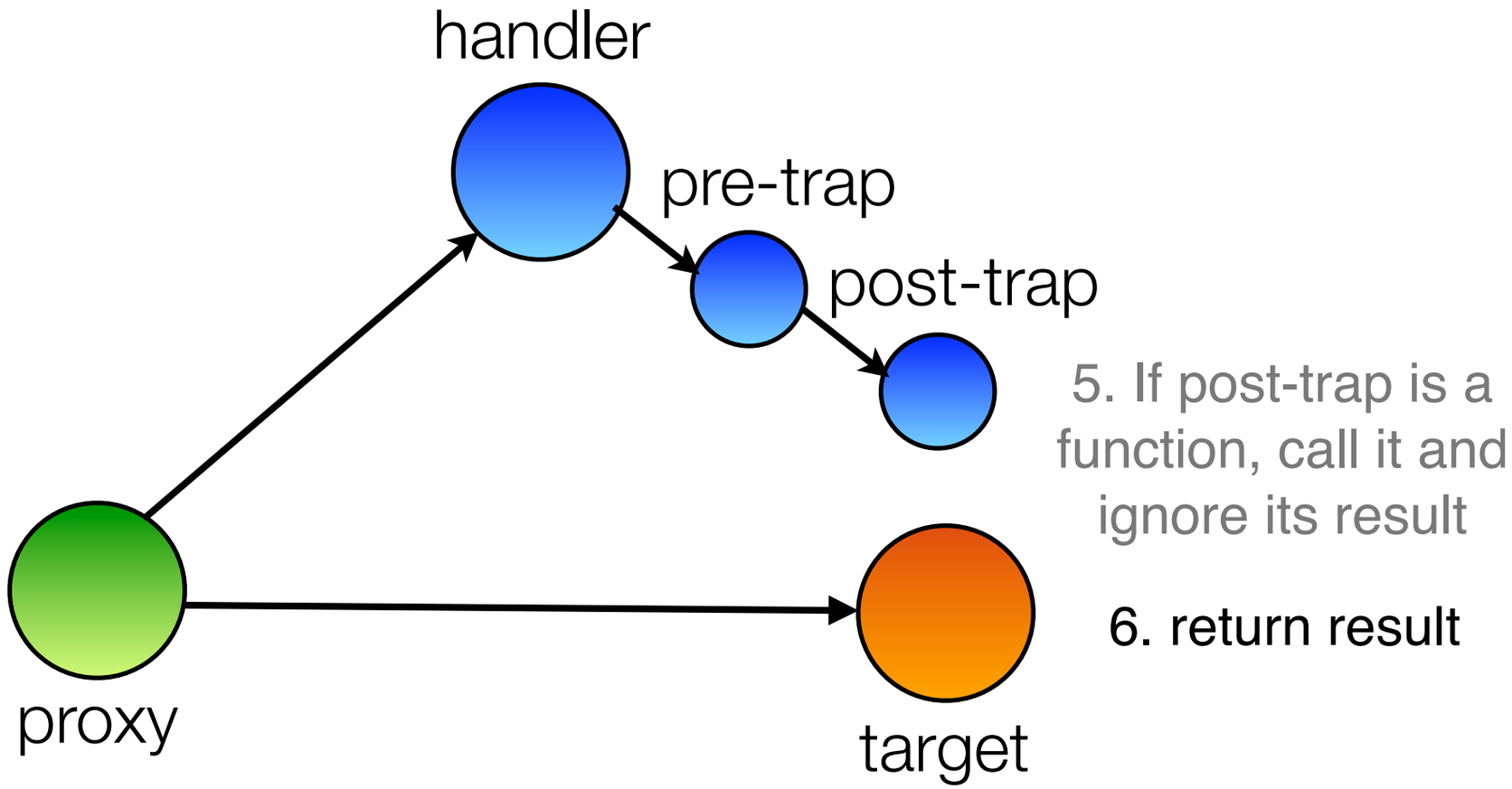

```
result = target.x;
```

Notification Proxies




```
postTrap.call(handler, target, “x”, proxy, result)
```

Notification Proxies




```
return result;
```

Notification Proxies

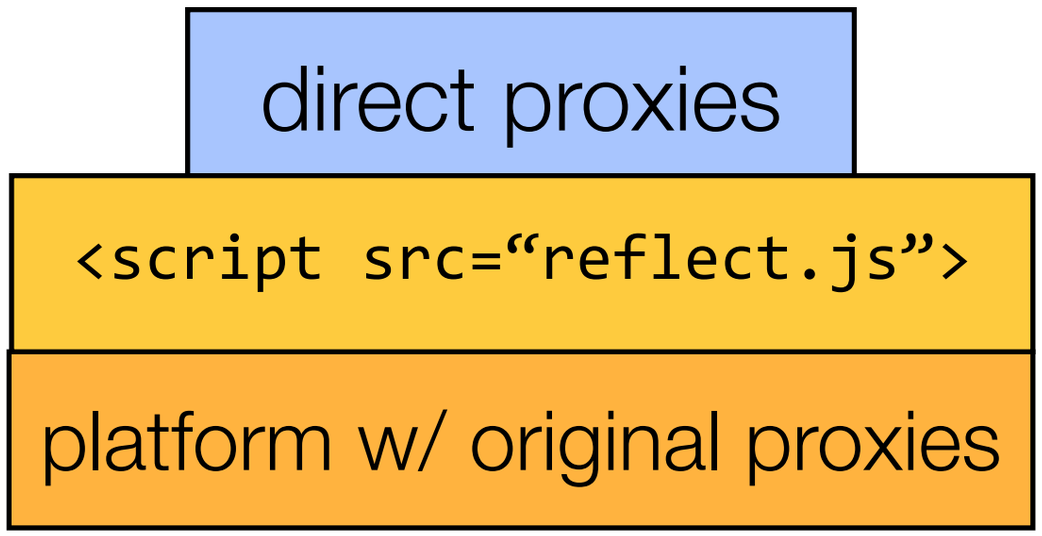
- Handler API same as for direct proxies
- “on” prefix to suggest callback-nature of traps

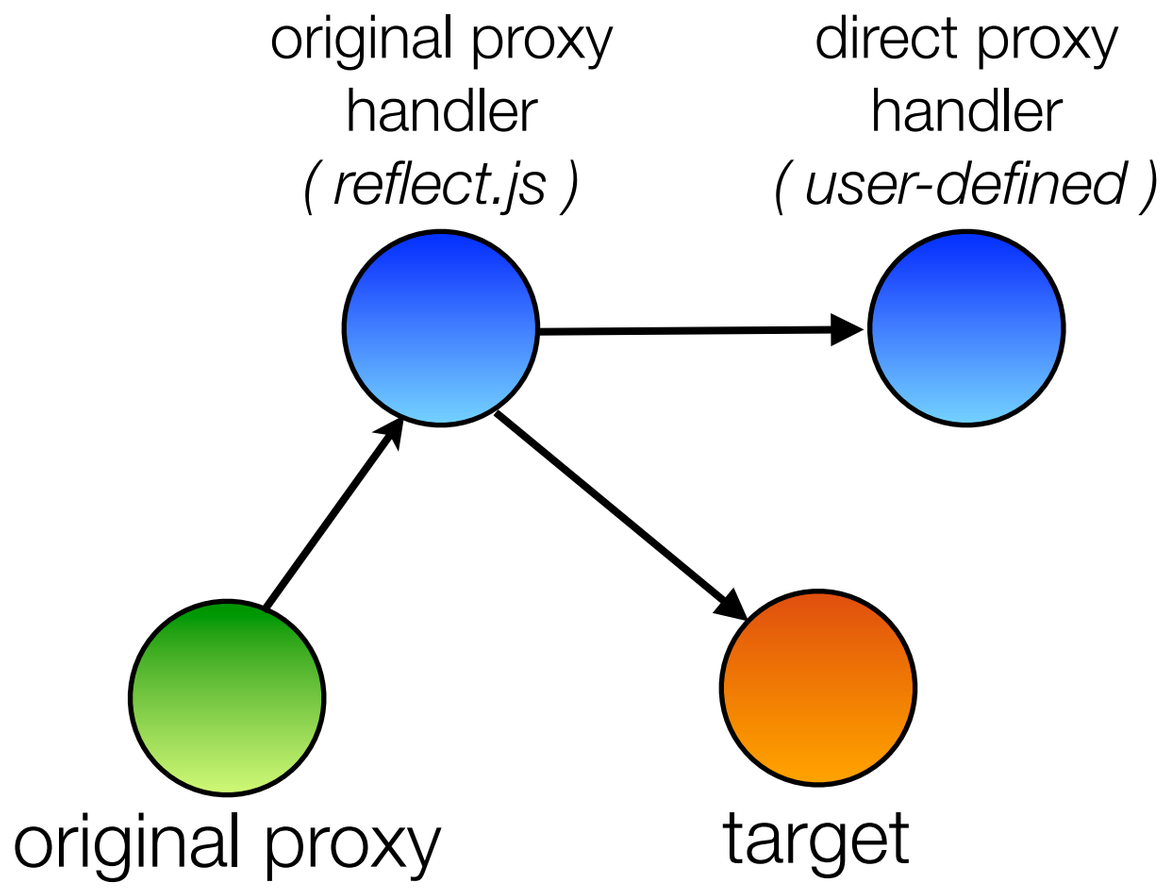
```
onGetOwnPropertyDescriptor: function(target,name)
onGetOwnPropertyNames:      function(target)
onGetPrototypeOf:           function(target)
onDefineProperty:           function(target,name, desc)
onDeleteProperty:           function(target,name)
onFreeze:                   function(target)
onSeal:                     function(target)
onPreventExtensions:        function(target)
onIsFrozen:                 function(target)
onIsSealed:                 function(target)
onIsExtensible:             function(target)
onHas:                      function(target,name)
onHasOwn:                   function(target,name)
onGet:                      function(target,name,receiver)
onSet:                      function(target,name,val,receiver)
onEnumerate:                function(target)
onKeys:                     function(target)
onApply:                    function(target,thisArg,args)
onConstruct:                function(target,args)
```

Prototype: reflect.js library

github.com/tvcutsem/harmony-reflect

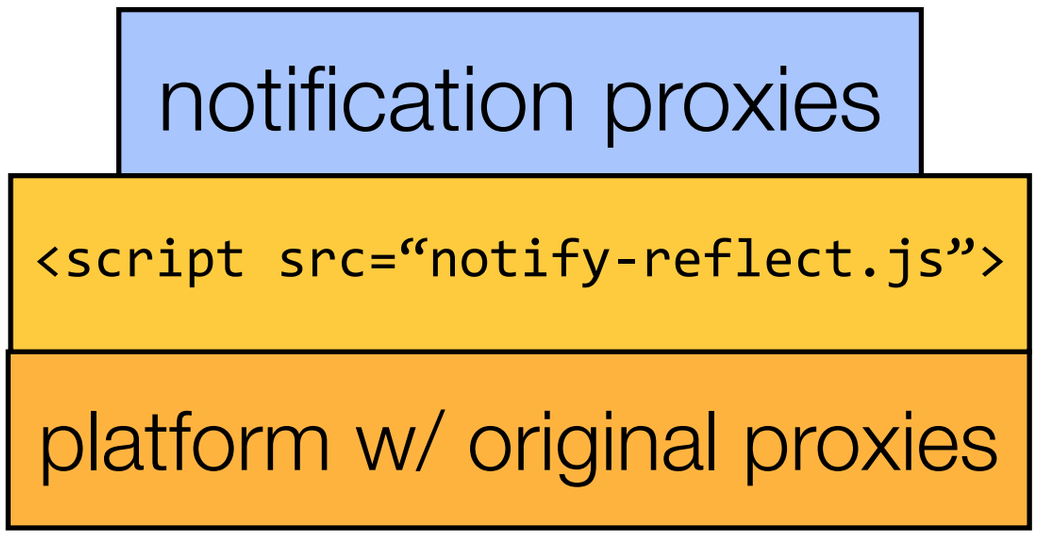
- Implements Direct Proxies on top of original Harmony Proxies
- Monkey-patches primordials to recognize emulated direct proxies

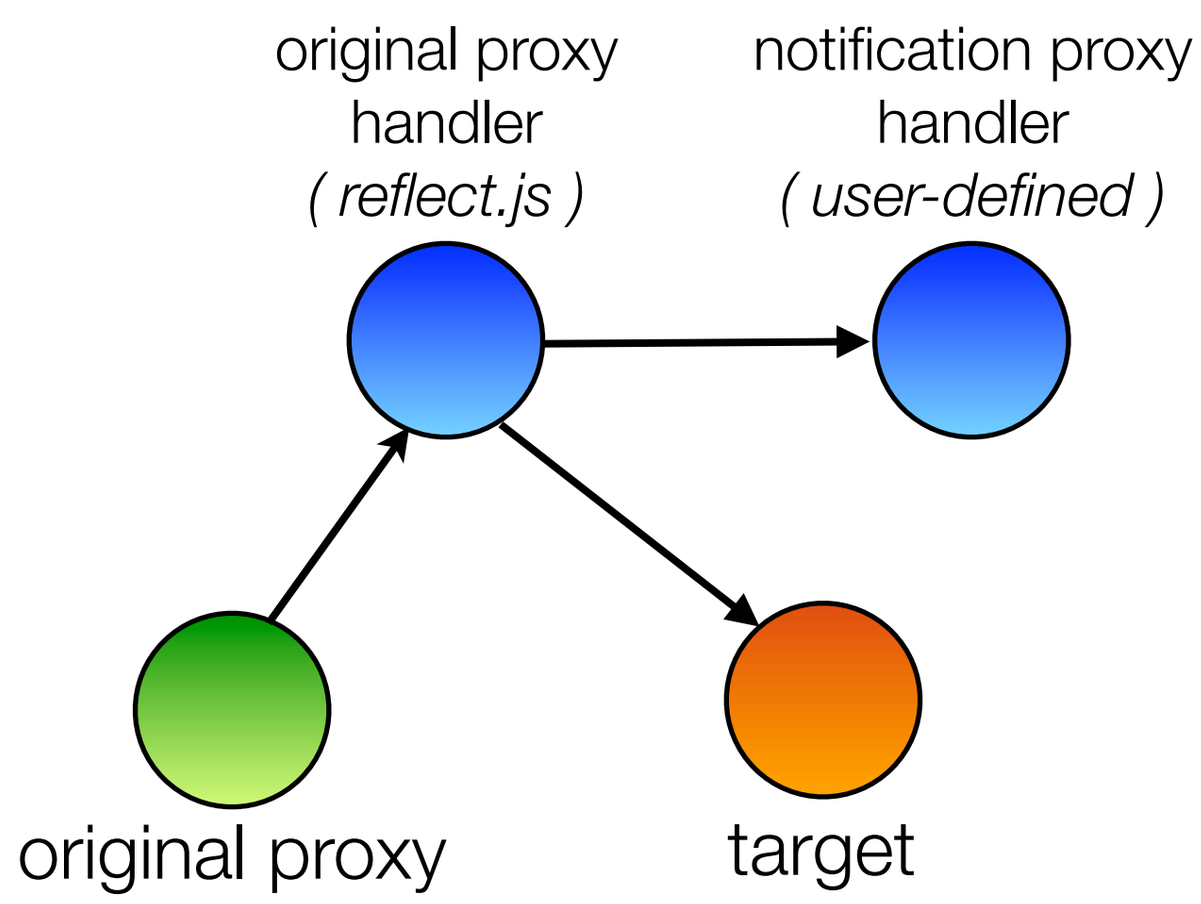




Prototype: reflect.js library

- Now also supports Notification Proxies
- Handler logic:
  - Direct Proxies: **850** LoC
  - Notification Proxies: **312** LoC

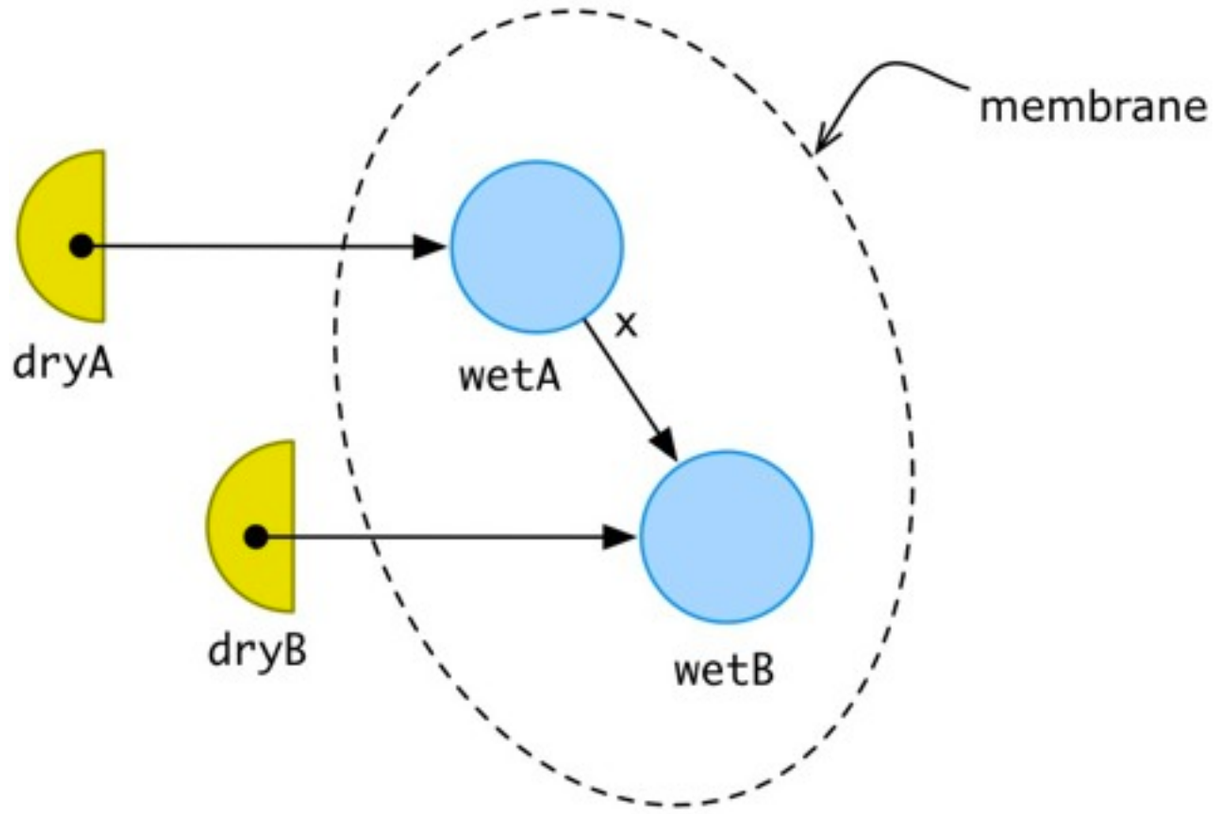




Membranes

- Goal: isolate two object graphs
- Litmus test for expressiveness of proxies
- Must be transparent: maintain invariants on both sides of the membrane

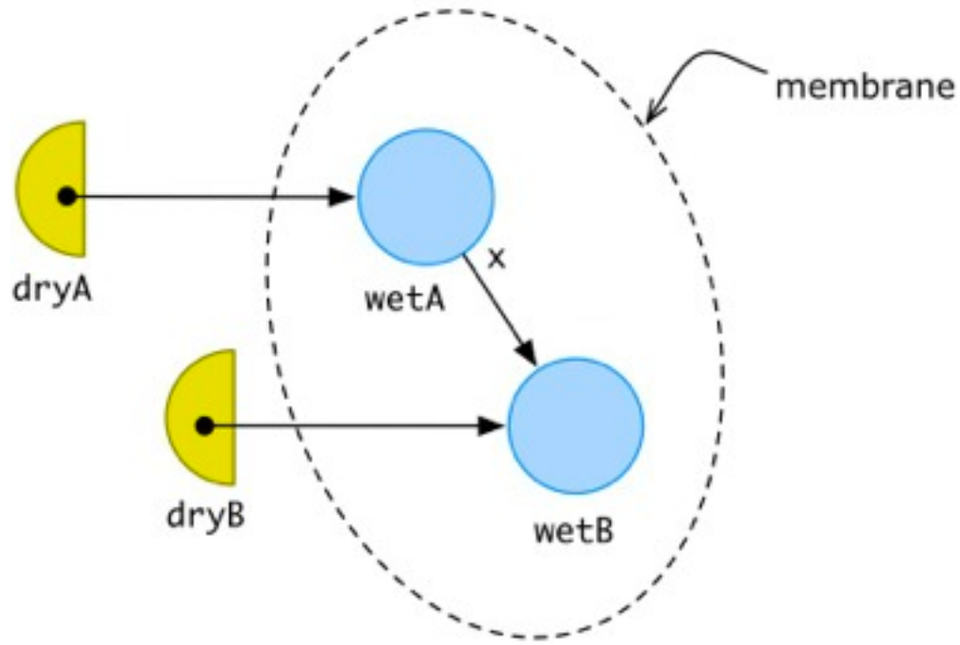
```
var wetB = {};
var wetA = { x: wetB };

var dryA = wet2dry(wetA);
var dryB = dryA.x;
```



Membranes with direct proxies: try 1

- Works fine as long as `wetTarget` doesn't have any invariants

```
var wetB = {};
var wetA = { x: wetB };

var dryA = wet2dry(wetA);
var dryB = dryA.x;
```



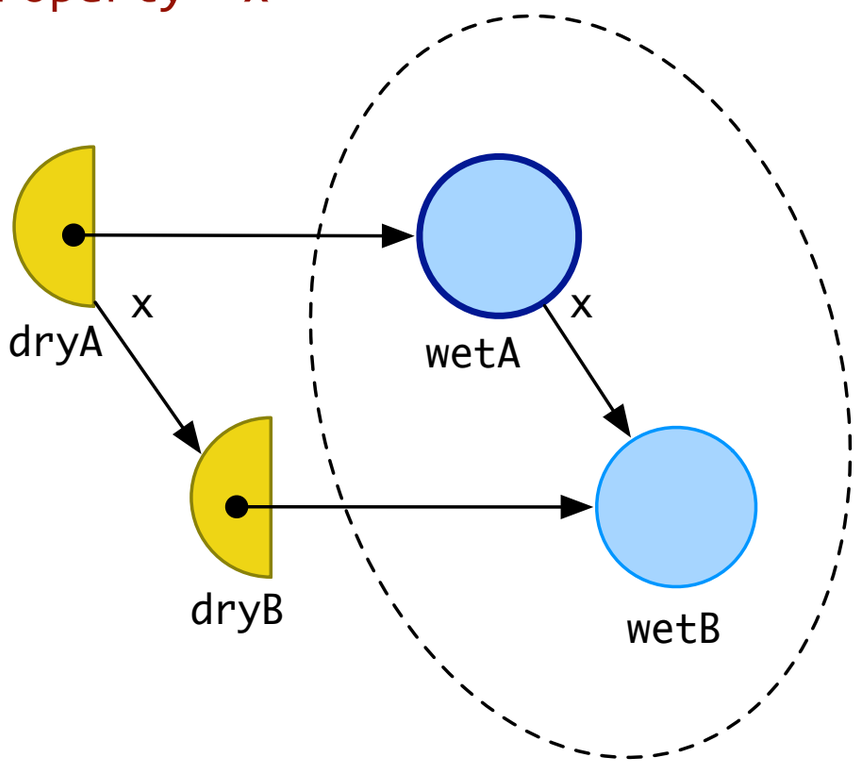

```
function wet2dry(wetTarget) {
  ...
  var dryProxy = new Proxy(wetTarget, {
    ...
    get: function(wetTarget, name, dryThis) {
      return wet2dry(Reflect.get(wetTarget, name, dry2wet(dryThis)));
    }
  });
  ...
}
```

Membranes with direct proxies: try 1

- Now assume `wetTarget` is frozen

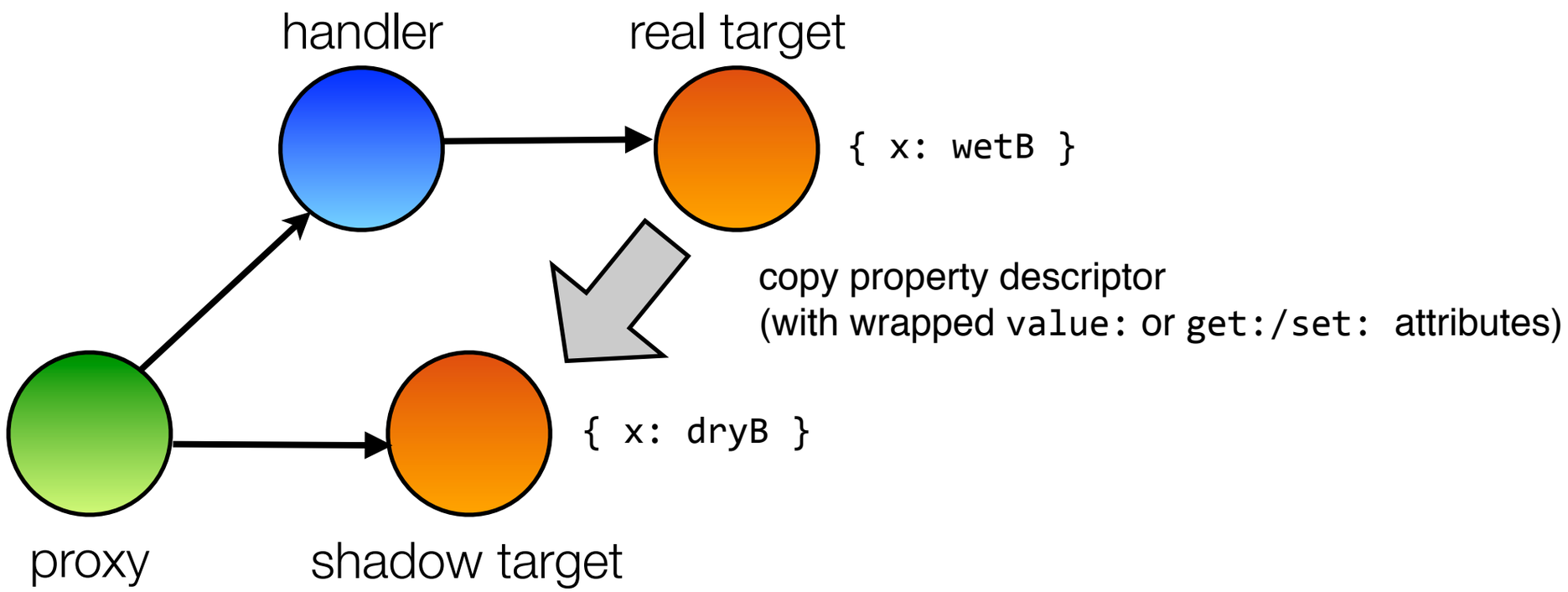
- Because `wetA.x` is non-configurable non-writable, and `wetA.x === wetB`, the proxy asserts that `dryA.x === wetB`

```
var wetB = {};
var wetA = Object.freeze({ x: wetB });
var dryA = wet2dry(wetA);
dryA.x // TypeError: cannot report inconsistent value for
                     non-writable, non-configurable property ‘x’
```



Membranes with direct proxies: try 2

- Use a “shadow” target: a dummy target object to store wrapped properties



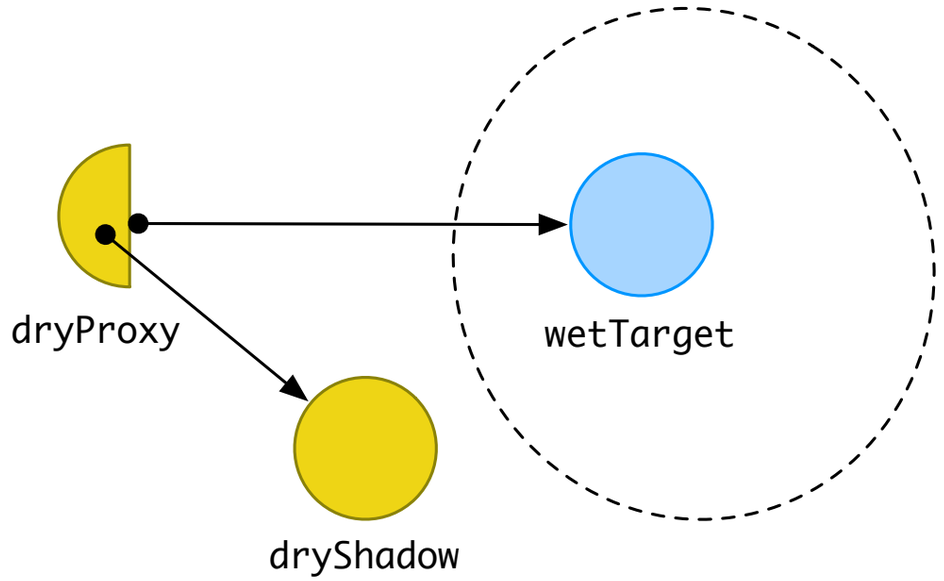
- General “solution”, not specific to membranes

```
var wetB = {};
var wetA = Object.freeze({ x: wetB });
var dryA = wet2dry(wetA);
var dryB = dryA.x; // ok: shadowTarget.x === dryB
```

Membranes with direct proxies: try 2

- In the case of membranes: shadow and real target are on opposite sides of the membrane

```
var wetB = {};
var wetA = Object.freeze({ x: wetB });
var dryA = wet2dry(wetA);
var dryB = dryA.x; // ok: shadowTarget.x === dryB
```

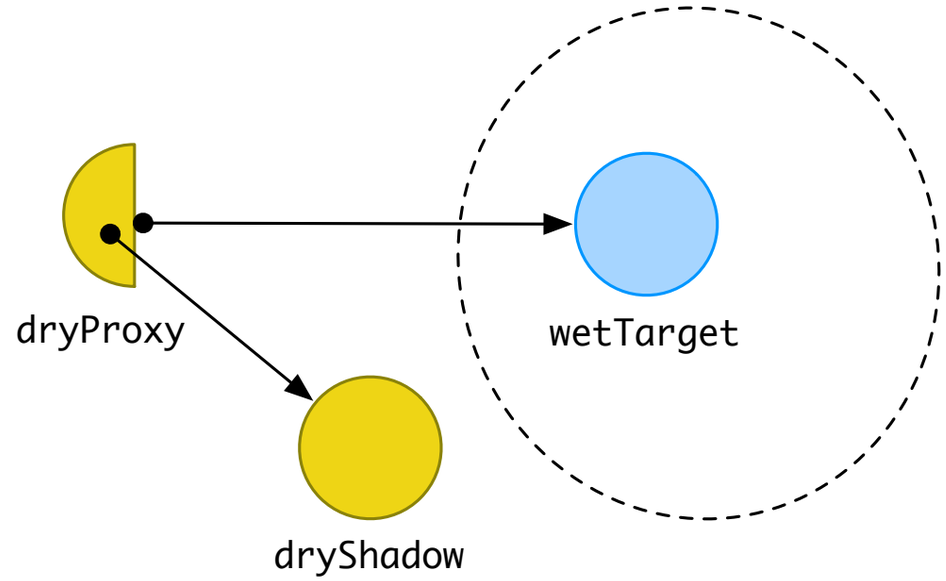



```
function wet2dry(wetTarget) {
  ...
  var dryShadow = {};
  var dryProxy = new Proxy(dryShadow, {
    ...
    get: function(dryShadow, name, dryThis) {
      // copy wet2dry(wetTarget[name]) to dryShadow
      return Reflect.get(dryShadow, name, dryThis);
    }
  });
  ...
}
```

Membranes with direct proxies

- Optimization: if no invariant is at stake, just ignore shadow target

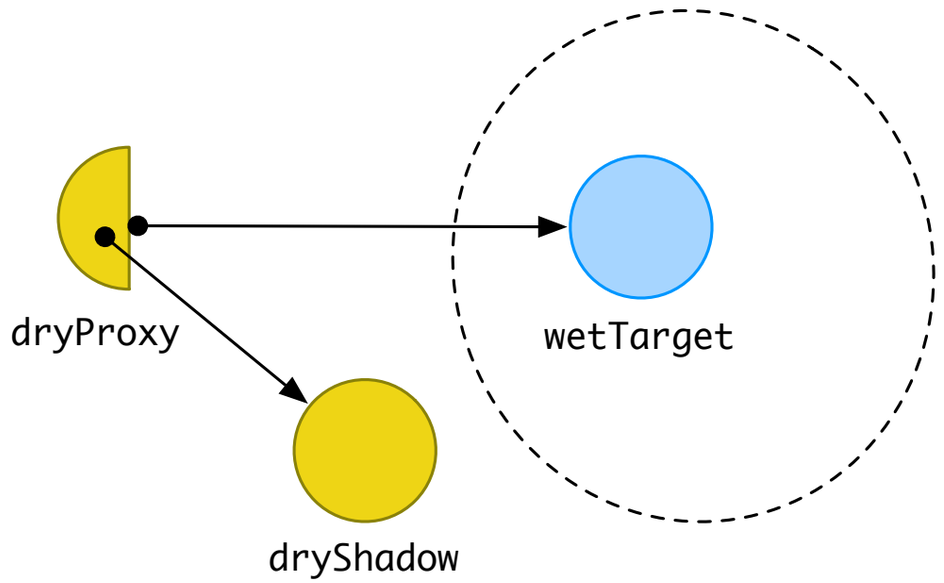
```
function wet2dry(wetTarget) {
  ...
  var dryShadow = {};
  var dryProxy = new Proxy(dryShadow, {
    ...
    get: function(dryShadow, name, dryThis) {

      // no-invariant case: fast-path, no copying
      if (isWritableOrConfigurable(wetTarget, name)) {
        return wet2dry(Reflect.get(wetTarget, name, dry2wet(dryThis)));
      }

      // invariant case: need to copy to shadow
      // copy wet2dry(wetTarget[name]) to dryShadow
      return Reflect.get(dryShadow, name, dryThis);
    }
  });
  ...
}
```



Membranes with notification proxies

- Must also use shadow target technique
- Naive implementation: always copy the accessed property from real target to shadow target in the pre-trap.
- When the notification proxy then forwards the operation, it will find the right value on the shadow.

```
function wet2dry(wetTarget) {
  ...
  var dryProxy = new Proxy(dryShadow, {
    ...
    onGet: function(dryShadow, name, dryThis) {
      // copy wet2dry(wetTarget[name]) to dryShadow
      return undefined;
    }
  });
  ...
}
```



Membranes: conclusion

- *Both* Direct Proxies and Notification Proxies can express membranes, with roughly the same implementation strategy:
    - Membranes with Direct proxies: 470 LoC
    - Membranes with Notification proxies: 402 LoC
- Direct Proxies can optimize for objects without invariants: no copying to shadow target needed
- Notification Proxies: optimizations are possible, but must copy each accessed property to the shadow target at least once

Micro-benchmarks

- Simple micro-benchmarks to get *some* indication of *relative* performance difference

- Setup: traverse large data structure wrapped in a membrane from outside the membrane

- Tested both frozen and non-frozen data structure (invariants vs. no invariants)

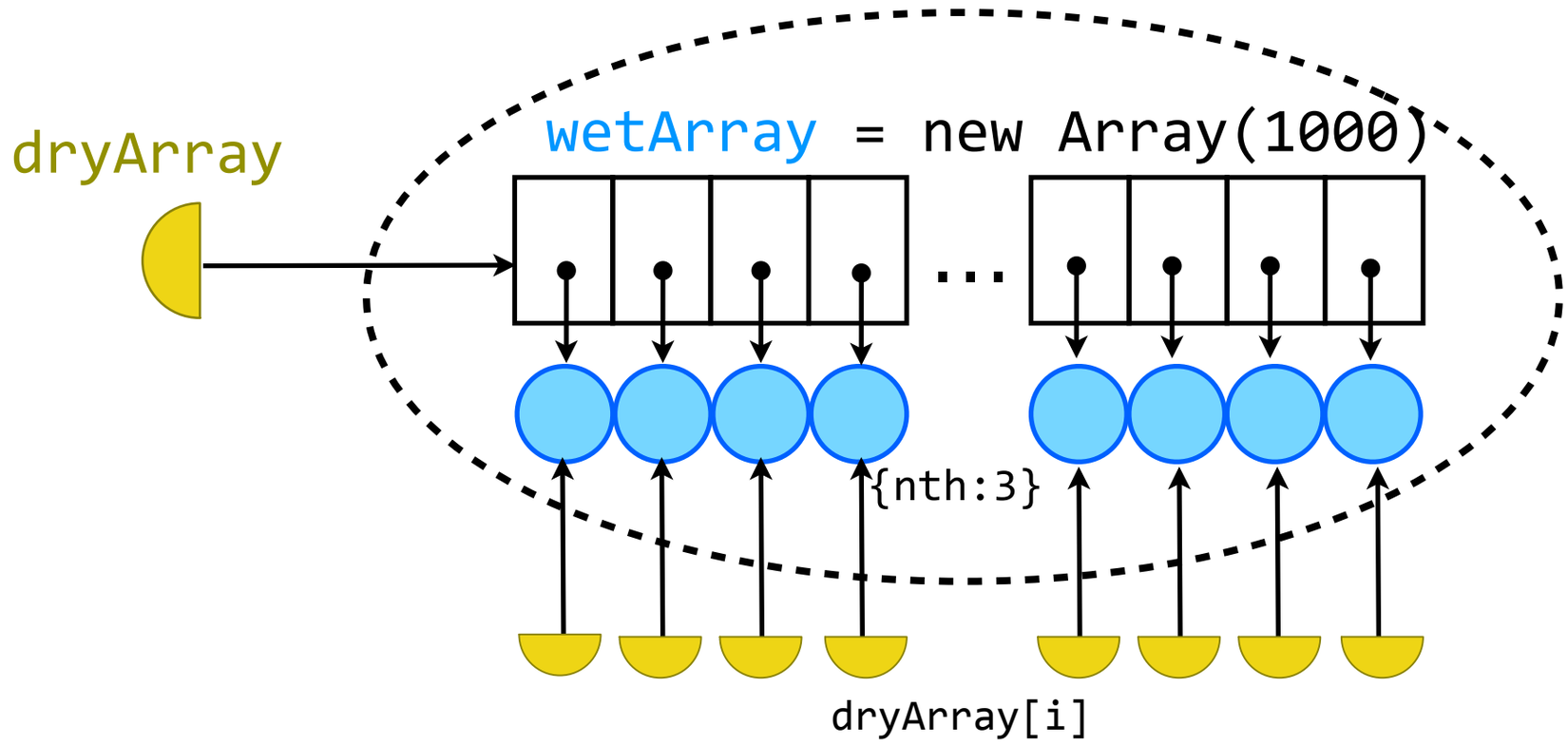
- Apples-to-apples: both Direct and Notification proxies self-hosted in JS

    - But: only look at *relative* perf. The absolute numbers are not interesting, built-in impls will be orders-of-magnitude faster.

Benchmark #1: Array Loop

- Creates a wrapper per entry, one property access per wrapper

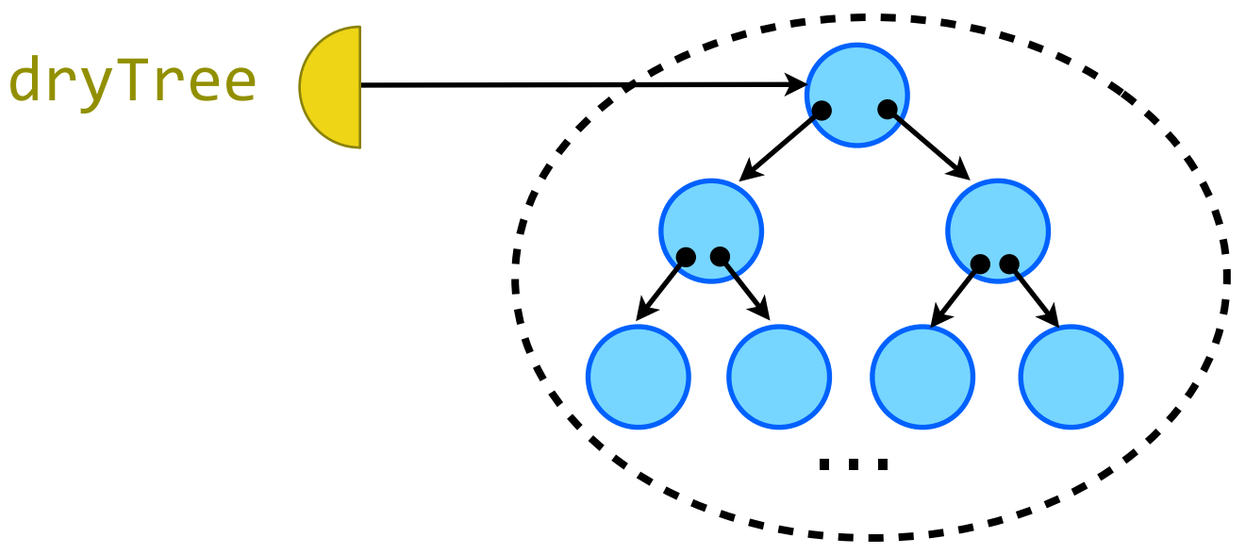
```
var dryArray = wet2dry(createArray(1000));
for (var i=0; i < 1000; i++){
  sum += dryArray[i].nth;
}
```



Benchmark #2: Tree Walk

- Creates a wrapper per node, 5x property access + 1x method invocation per node

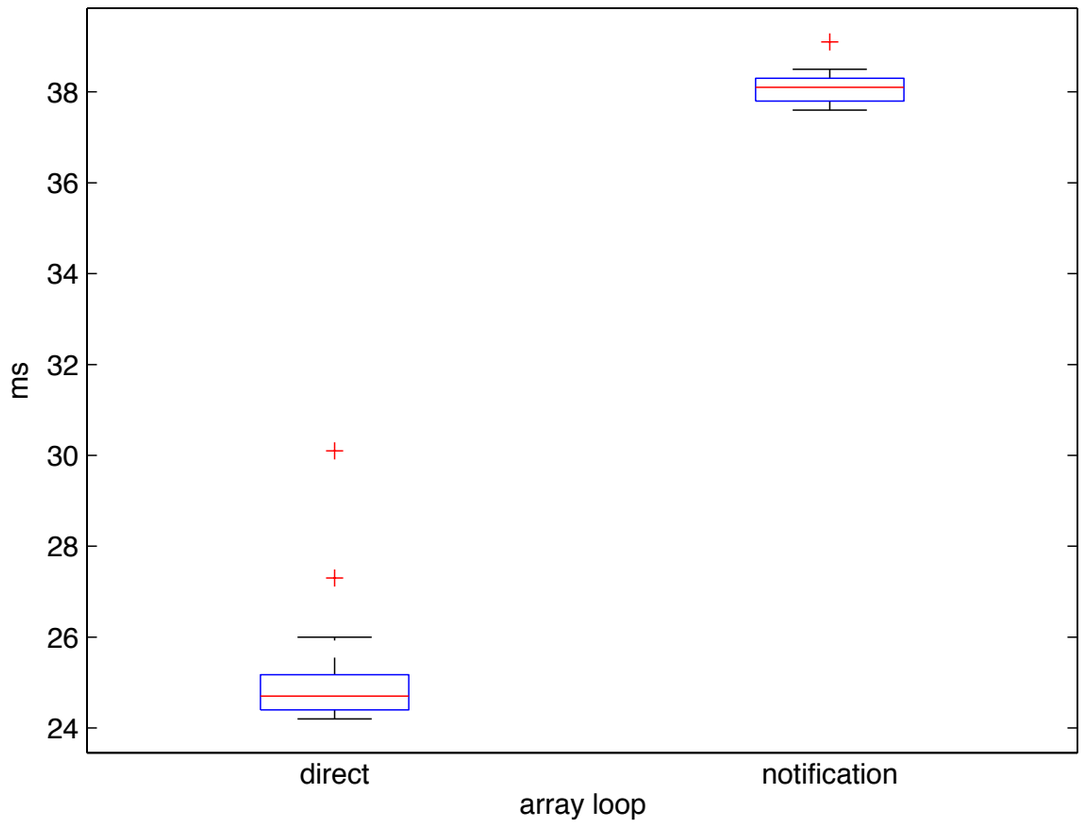
```
// binary tree of depth 10 = 1023 nodes
wetTree = binaryTree(10)
```



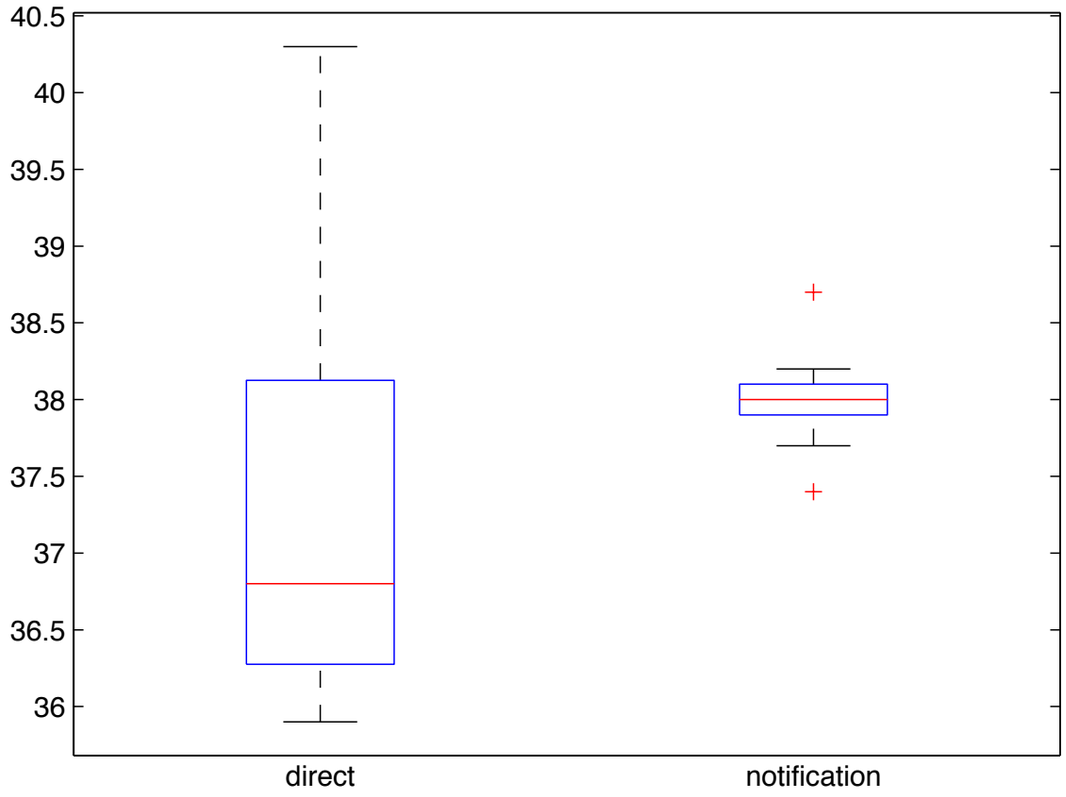

```
function traverse(dryTree) {
  var l = dryTree.left ? traverse(dryTree.left) : 0;
  var r = dryTree.right ? traverse(dryTree.right) : 0;
  return dryTree.depth() + l + r;
}
```

Array loop (Firefox 20)

non-frozen



frozen



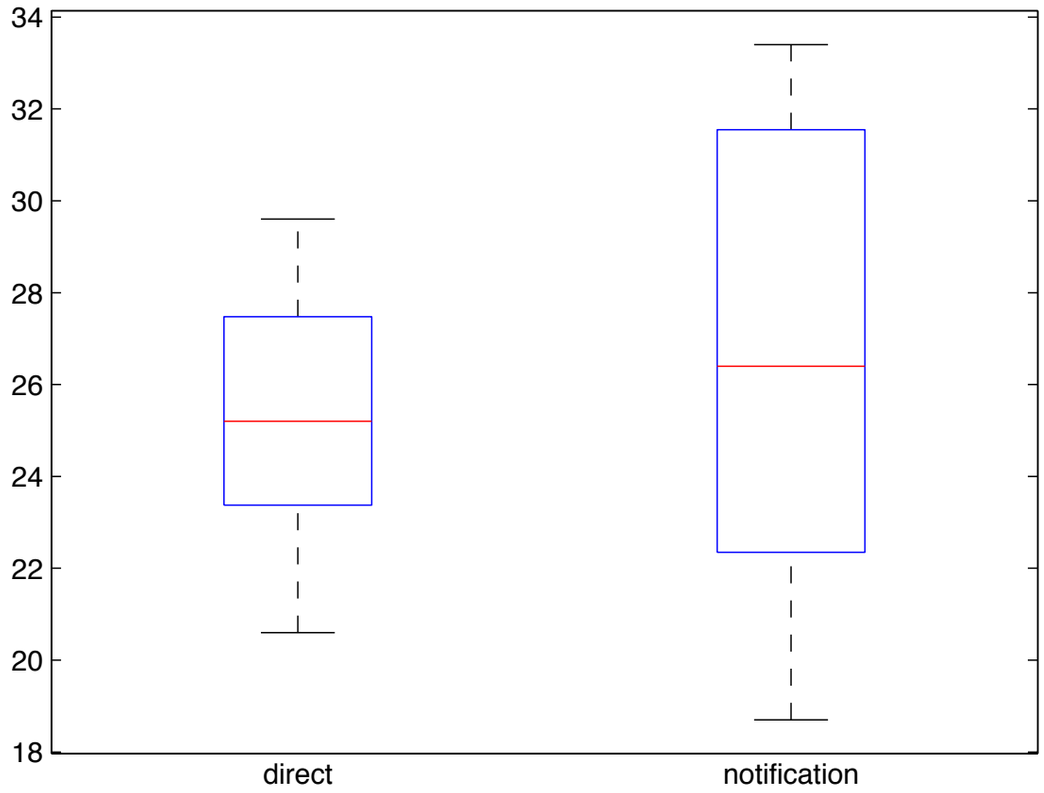
-51.04%

-2.23%

(box plot of 16 runs in same browser session, each individual run = average of 10 traversals)

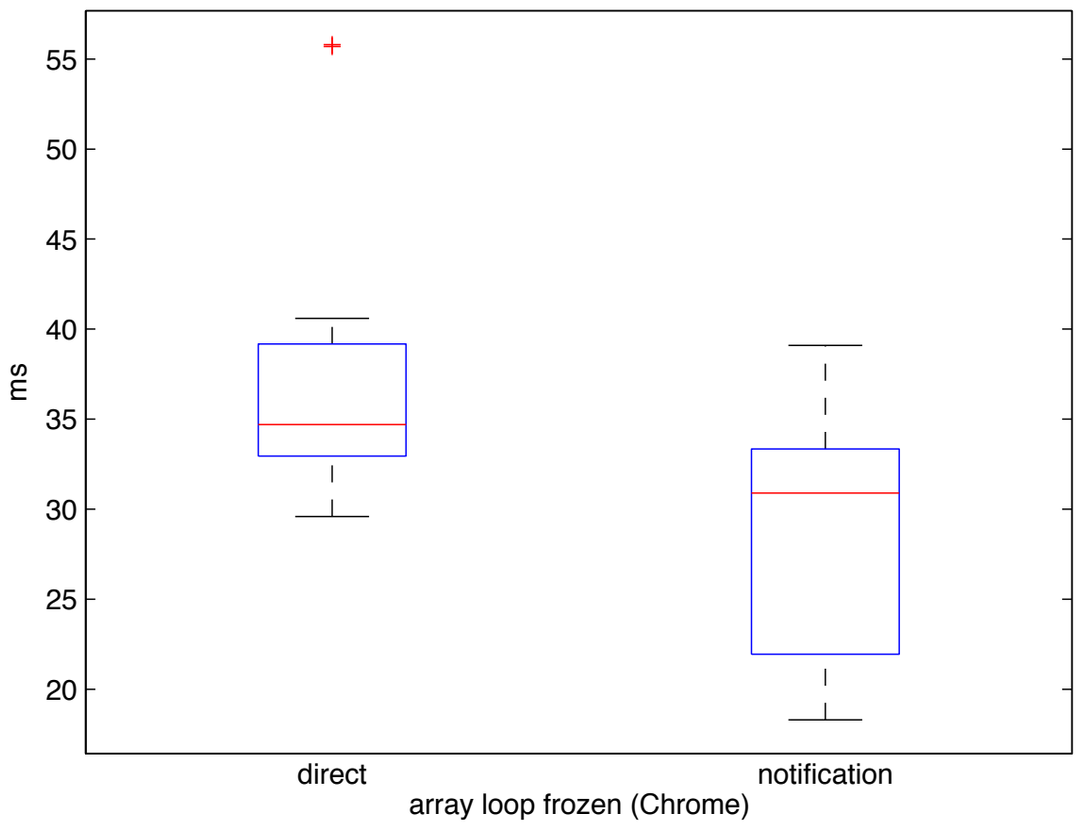
Array loop (Chrome 26)

non-frozen



-5.85%

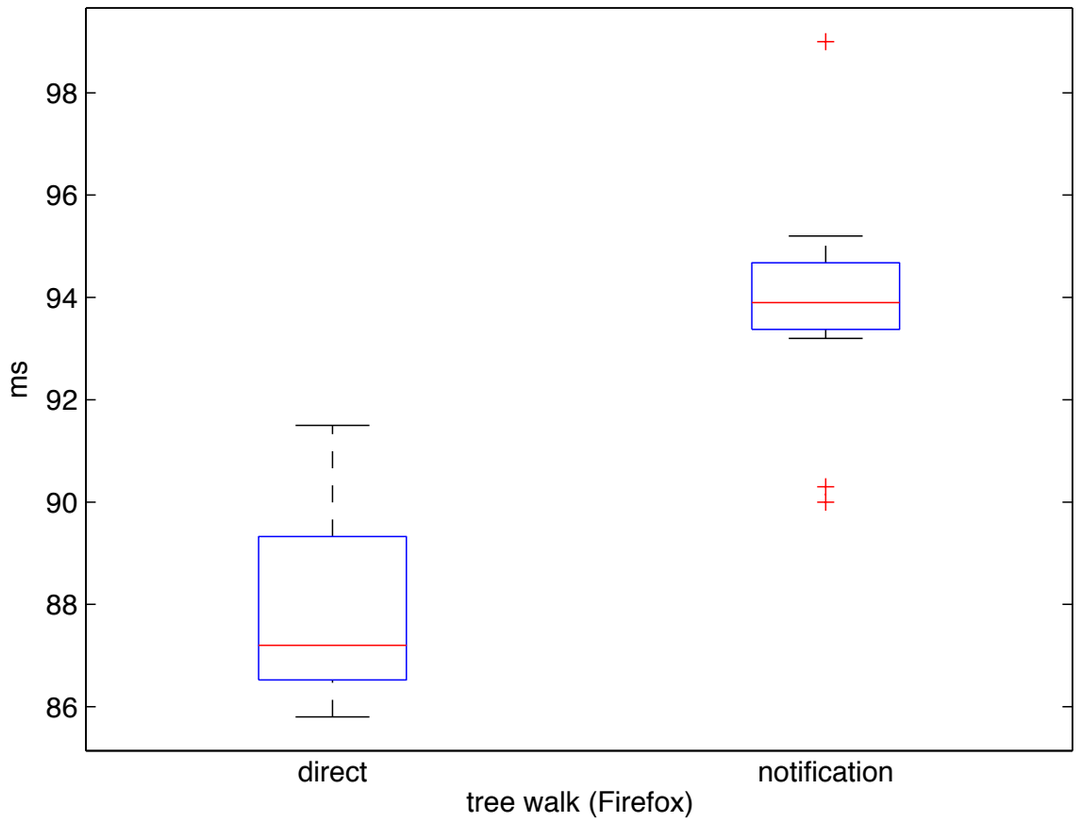
frozen



+22.24%

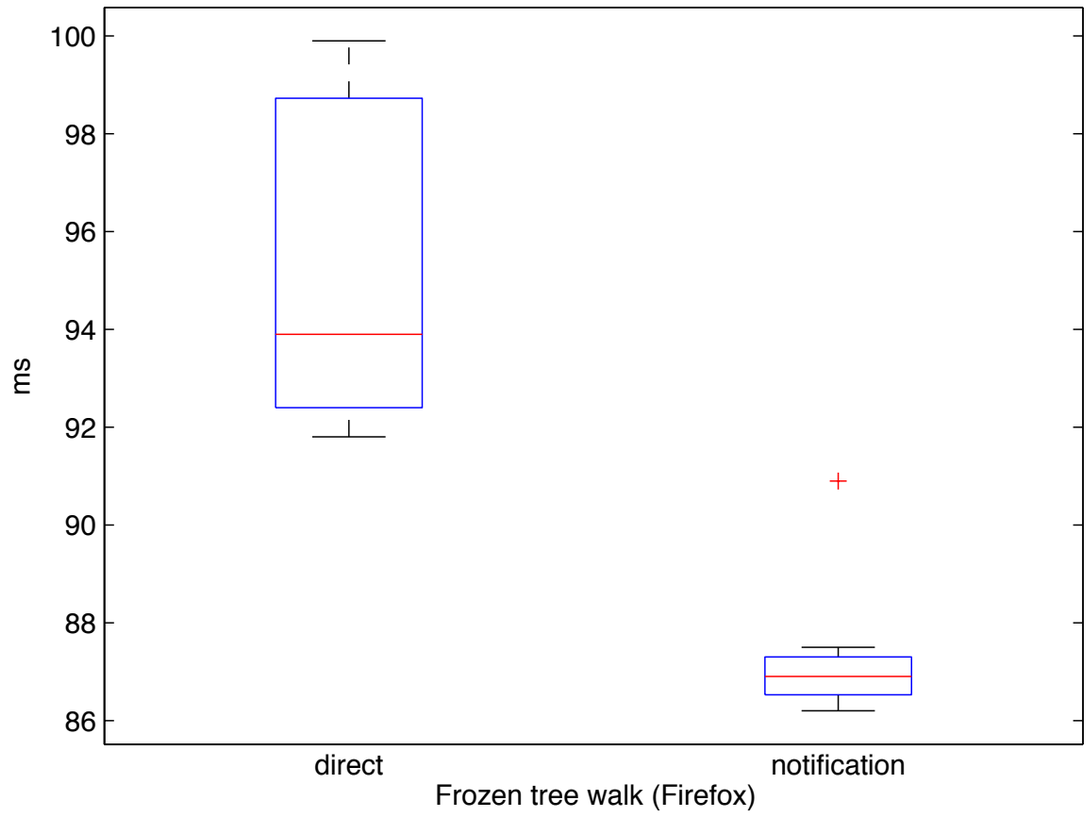
Tree walk (Firefox 20)

non-frozen



-6.94%

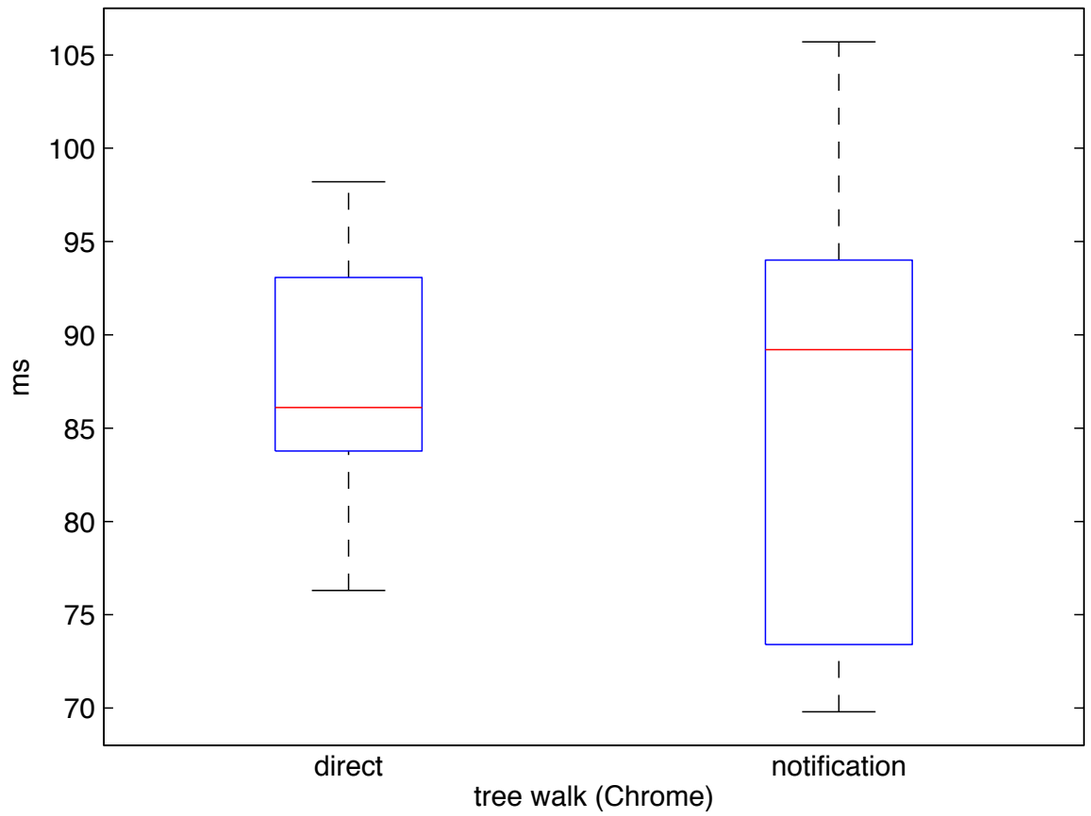
frozen



+8.84%

Tree walk (Chrome 26)

non-frozen



-2.41%

frozen

+33.38%

Micro-benchmarks

- As always with micro-benchmarks, take these numbers with a grain of salt
  - Ample room for optimization in the membrane code
  - Built-in Proxy/WeakMap implementations still young
- Inconclusive. My gut feeling: either API can be made efficient.

	Firefox 20	Chrome 26
Array Loop	-51,04%	-5,85%
Frozen Array Loop	-2,23%	22,24%
Tree Walk	-6,94%	2,41%
Frozen Tree Walk	8,84%	33,38%

Table: relative perf gain/loss of notification proxies compared to direct proxies

Conclusion

- Notification Proxies:
  - Pro: simpler design, easier to spec
  - Con: “virtual objects” must always copy each accessed property at least once (direct proxies must only copy for objects with invariants)
- Perf: let’s not draw any conclusions just yet

References

- Self-hosted implementation of direct proxies:
  https://github.com/tvcutsem/harmony-reflect/blob/master/reflect.js

- Self-hosted implementation of notification proxies:
  https://github.com/tvcutsem/harmony-reflect/blob/master/notification/notify-reflect.js

- Membranes with direct proxies:
  https://github.com/tvcutsem/harmony-reflect/blob/master/examples/membrane.js

- Membranes with notification proxies:
  https://github.com/tvcutsem/harmony-reflect/blob/master/notification/membrane.js

- Benchmarks: https://github.com/tvcutsem/harmony-reflect/tree/master/test/membranes

- Paper with details on direct proxies and the shadow target technique:
  http://soft.vub.ac.be/Publications/2013/vub-soft-tr-13-03.pdf